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Metals and Alloys

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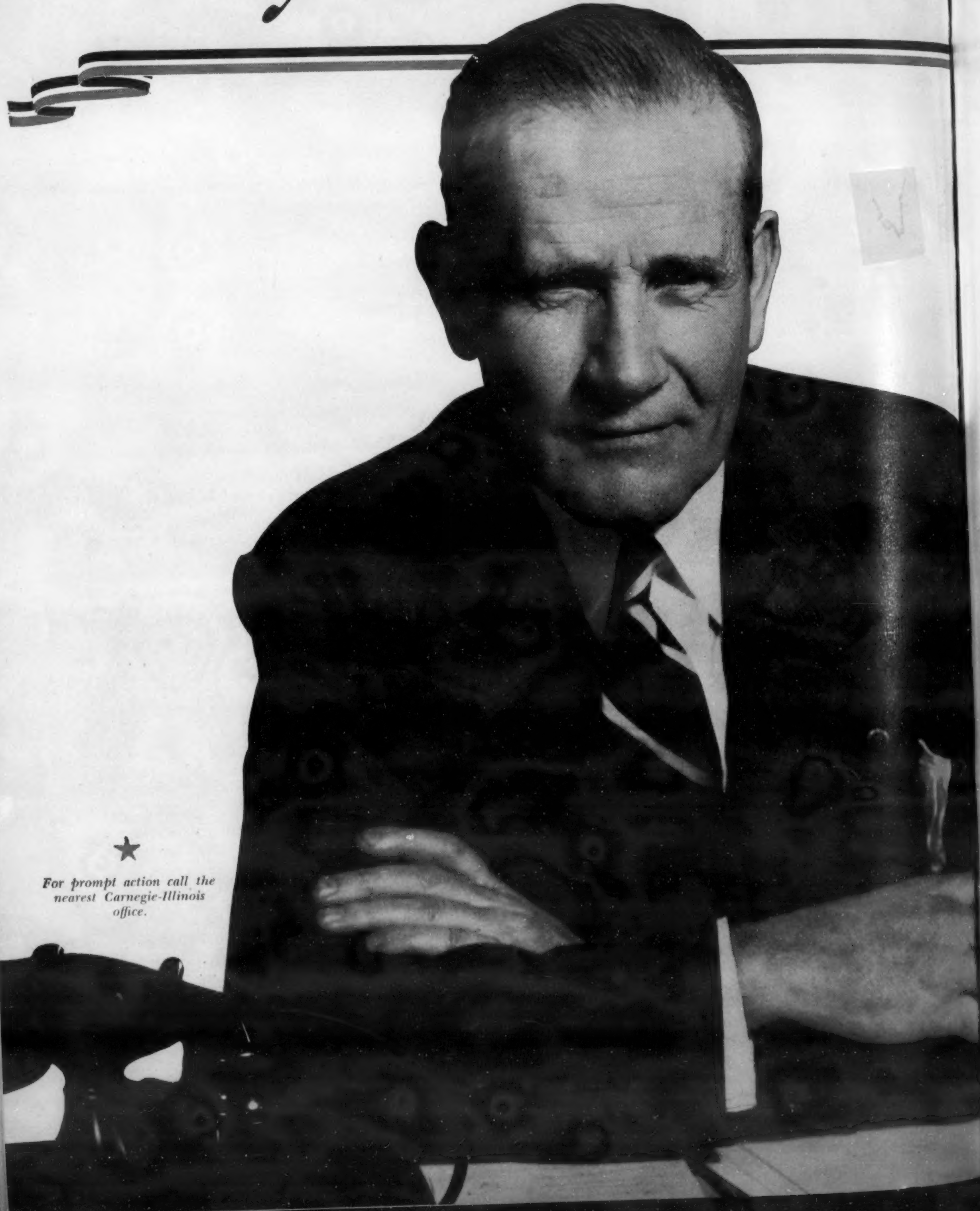

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Feature Section

Beryllium

Dr. Sawyer was asked to "debunk" some of the statements in the press regarding the so-called strategic nature of beryllium. He has authoritatively done this.

Magnesium in Aircraft

We wanted some authoritative information regarding the role of magnesium and its alloys in aircraft. Dr. Woldman has fully supplied the need.

Aircraft Stampings

Stampings of several kinds of material are extensively used in airplanes. Mr. Chase describes their production in the great plant of the Douglas Aircraft Co. Modern plants have become chiefly engaged in doing sheet metal work instead of working with wood.

An Ordnance Problem

During the World War, flakes and cooling cracks in forgings were a problem. They still are. The present situation as related to the Defense Program is discussed by Mr. Foley, a metallurgical engineer of broad experience in this field.

Aircraft Laboratory

What a modern laboratory means to the production of high-grade airplanes and to the Defense Program is demonstrated by Mr. Woods in a pictorial article.

Tin and Bearings

The relation of the strategic metal—tin and antimony—to the bearing situation is reviewed in this second installment.

Armor Plate

The electric steel industry and its relation to the production of armor plate is portrayed from the viewpoint of the Republic Steel Corp.

Non-Destructive Testing

All airplane tubing in particular must be as flawless as possible. Mr. Knerr describes a new apparatus for the electrical detection of defects in tubing and bars, ferrous or non-ferrous, magnetic or non-magnetic.

Engineering Digests

Contraction in Cast Iron

Working with castings literally as big as the side of a house, Longden (page 528) finds that thick sections contract more than thin where thick and thin sections are linked in close proximity.

Belgian Pickle

McLeod (page 550) found himself in a pretty pickle when the Germans invaded Belgium while he was in that country obtaining data on a new pickling process for his British readers. The bath consists of ferrous sulphate, hydrochloric acid, sulphuric acid and an inhibitor, and is claimed to be extremely fast. A critical discussion offers counter claims.

Austempering Iron Castings

Still ga-ga over having Elmer Legge's article on austempering in our August 1939 issue officially cited as the best single article published in the industrial press last year, your editors note that Bartholomew austempers gray iron and Cowan does it to malleable (page 549).

Brake Drums

Which shall it be—cast iron or steel for heavy duty brake drums? Crosby & Timmons (page 564) plump for gray cast iron and, in addition, recommend the use of molybdenum to increase strength.

Bismuth Alloy Forming-Dies for Aircraft Sheet

Chase's feature article in this issue and the first part of a composite on "Forming Aircraft Sheet" (page 542) stress the utility of zinc alloy dies for forming light metal or light-gage stainless sheet. Rowe in the same composite, however, promotes low-melting bismuth-base alloys for the same purpose, claiming lower long-time die costs, exact die sizing and freedom from warpage.

Fatigue of Light Metals

Aluminum and magnesium alloys, although low in fatigue strength, need not always be skipped over on that account—even low fatigue strengths are often high enough, and redesign may permit the use of light metals. Gürtler (page 572) advocates for design purposes the use of fatigue data based on the beginning of damage formation of cracks—rather than on actual failure, and describes a method for determining points on the "damage curve".

The Metal Industries and Defense

Metals and their alloys—especially certain ones—are indispensable to any program of national military preparedness and defense.

Because of the tremendous program which our Government — in the face of danger from the social revolution which dominates Europe — is engaged in to the hilt, the editors of METALS AND ALLOYS devote this issue in particular to articles and discussions bearing on certain phases of the national program.

So vast and complicated is the relation of metals and alloys to any such program of military preparedness—involving battleships, cruisers, submarines, guns of all types, airplanes, tanks, armor plate, and so on—it has been impossible to bring into one issue discussions covering all these and other phases. Many subjects, also, cannot be even touched on because of the circumstances involved in the program.

In a spirit of patriotism and enterprise, however, we present an array of editorial expressions by competent authors which are related in one way or another to this expansive undertaking. We also thus celebrate, as is our custom each year, the National Metal Congress, held in Cleveland this month, by such a special issue.—E. F. C.

Our Cover

Through the courtesy of the U. S. Navy and War Departments, and the cooperation of the N. Y. Times Wide World photographic organization, we are able to present on the cover a group of several types of American defense equipment—this issue being devoted exclusively to articles and discussions related to the Government's Defense Program.

For many of the illustrations used in the early part of this issue—battleships, torpedo boats, submarines, airplanes, guns and so on—we are indebted also to the Navy and Army.—The Editors.

Strategic Metals

In Vol. 1, No. 1 of METALS AND ALLOYS, for July, 1929, we published an article by Major Roger Taylor, of the Ordnance Department, U. S. Army, on "Strategic Raw Materials." Most of what was said there is directly applicable today, the more notable changes being that the chief source of platinum is now Canada instead of Russia and Colombia, and that the development of molybdenum high speed steels has so eased the tungsten situation that, although tungsten is still classed as a strategic material, this seems to be more from the aspect of its use in some projectiles, rather than in tools.

We hear a good deal of the importance of machine tools in the defense picture, but there are no worries about the tools themselves. Domestic tungsten can be supplied for cemented carbide tools and molybdenum high speed steels are so far advanced that an enforced substitution of them for 18:4:1 and other high tungsten tool steels, would scarcely be even an inconvenience.

The antimony situation has changed, too, for beside the feasible replacement of antimony in shrapnel balls and bullet cores by use of alkali or alkaline earth metals to harden the lead instead of antimony, it has been shown by the National Bureau of Standards, the Bell Telephone Laboratories, and others, that calcium-hardened lead will serve excellently in storage battery plates.

In 1929, the model T was still in production. While metallurgical changes have not been as striking nor as obvious as the differences between the 1929 and the 1941 cars, yet changes for the better have occurred in the whole strategic metals situation, even though some of these are not as clear-cut as in the cases of tungsten and antimony.

The chromium situation is probably more severe than in 1929 because stainless steel has come into so much greater popularity. It may prove a serious competitor to aluminum for aircraft construction, so that in future years we may have to class it as essential for that purpose. This is not yet the case, since aluminum is holding its own in that field and even plastics may serve to a limited extent. Lack of stainless will not seriously handicap the aircraft program, but the many needs for stainless in the chemical industry, for chromium in aircraft valves, in tool steels, and in various constructional steels, will have to be met.

The possibilities and limitations in replacement of

(Continued on page 470)

"It's because we are turning out more parts, at lower cost," says this operating manager, "but that is only part of the story. Inland Quality Sheets and Inland Co-operation help us give our customers finer products and better service."

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METALLURGICAL ENGINEERING IN PREPAREDNESS AND DEFENSE

Both ferrous and non-ferrous metals and their alloys are so manifestly essential to any program of military preparedness that national defense would be impossible without them. Modern efficient weapons of war—battleships, cruisers, aircraft carriers, destroyers, submarines, guns of all types, airplanes, tanks, armor plate of all degrees of protection, and many other products—could not be produced without these materials.

In recognition of these facts and of the Government's tremendously expansive program of Preparedness and Defense, the October issue of METALS AND ALLOYS *is devoted exclusively in its feature section to articles and discussions which in some manner are directly or indirectly associated with the Government's program. Naturally not all phases of the relation of metals and their alloys to preparedness can be covered in such an issue. As the special issue of the year, the October number is also associated with the National Metal Congress which meets in Cleveland, Oct. 21 to 25.*

The main theme of the issue is "Metallurgical Engineering in Preparedness and Defense." The leading discussions or articles cover in general the relation of the metal industry to the Government's preparations for defense, metallurgical problems involved in the preparedness program—both ferrous and non-ferrous—by authors who speak with authority.

Another feature of the issue is a symposium or review of the relation of, and the present situation regarding, the seven strategic materials—for the most part written by men thoroughly posted in the respective fields.

In addition to these introductory presentations, there are a number of articles which treat of many subjects which enter into the general preparedness program—the airplane, armor plate and electric furnace capacity, tin and bearing metals, tinplate and solder, beryllium and some of its alloys, commercial heat-treating laboratories, problem of flakes and cooling cracks in forgings, role of aluminum and magnesium in the program, and others.

It is planned that not only the October issue shall contain such articles tied to the defense program, but also the November and subsequent numbers will feature some of them.

Two articles of a general nature serve to introduce this issue.

Dr. George B. Waterhouse, of the metallurgical department of the Massachusetts Institute of Technology, Cambridge, Mass., discusses some of the ferrous metallurgical problems in the defense program. He is widely known among metallurgical engineers here and abroad.

Dr. Charles F. Lindsay, Westport, Conn., a consulting engineer, reviews some of the non-ferrous problems in the preparedness program. His experience in the non-ferrous industry has been extensive.

Some Ferrous Problems in the Defense Program

By GEORGE B. WATERHOUSE

THE DEFENSE PROGRAM WILL RECEIVE the earnest and enthusiastic support of every metallurgist connected with the iron and steel industry. Without their efforts it cannot succeed because iron and steel constitute the backbone of practically every industry contributing to national defense and the correct and proper irons and steels cannot be produced without careful metallurgical control and supervision. The subject of the problems that confront the metallurgical engineer is very large and only part of them will be considered in this article.

Production—It is evident that there will be need for every ton of material that can be produced. Even now the plants are at virtual capacity and our program is only getting under way. This means that every producing unit and process will have to be studied intensively and production maintained and increased. This may seem to be a familiar matter to the metallurgist, and fortunately this is true, but the question will be complicated by a number of new factors. For instance, quality must be rigidly maintained to meet the demands for high quality products, such as ordnance material, hitherto made on a comparatively small scale and by leisurely methods not considered as tonnage methods. Also in regard to the ordinary tonnage materials methods must be worked out which will give greater output than at present while still maintaining quality.

This matter of production is so important that some of the problems may be considered in detail.

Pig Iron—In regard to pig iron more and more will be required to supply the foundries and steel plants because of the increased demand for finished products, and because the supply of suitable scrap will constantly decrease. This is already evident in the increasing price of scrap and the discussions regarding placing an embargo on shipments of scrap to other countries. We do not need new kinds of pig iron but more of the kinds already being produced. Part of the increased tonnage can be obtained by putting into blast some or all of the idle furnaces, about 40 (out of a total of 215) being idle at the present time, most of the 40 being the smaller, older and least efficient of the furnaces now in the country.

Consideration may be given to the building of new modern furnaces at the proper locations, but this would take from 9 to 18 months, and it is becoming increasingly hard to get deliveries of blowing engines and other items of equipment desired. In regard to raw materials we can step up the production of iron ore and flux, either limestone or dolomite, and fortunately we have plentiful supplies in various localities, but we are not so well off in regard to coke, and the building and equipping of new batteries of coke ovens would again take considerable time.

The most promising way of increasing pig iron production at most of the existing plants has already been mentioned, namely, the intensive study by the metallurgical engineering staff of every detail of the blast furnace process. Fortunately, the groundwork has been done in recent years and the effect of various factors on production and quality has been carefully studied, such as crushed, screened and graded ore, flux and coke, methods of charging, effect of increased volume of blast and of higher temperatures, studies of stove operation and increased stove efficiencies, effect of the use of sintered fine ores and studies to reduce flue dust losses. Also, the effects of various slag compositions on easy running and on quality and output. The metallurgist can and must apply this body of knowledge to the individual

plant with which he is connected.

It would seem as though the main difficulties would be in the supply of coke and in maintaining the quality of coke in face of constantly increasing demands for more coke production, and the problem will be to keep up and increase pig iron production and maintain quality while using soft friable coke possibly higher in ash and in sulphur than at present. A careful study of each factor in the blast furnace practice may easily lead to an increase of 5 to 25 tons or more each day per furnace, which will mean a great deal in terms of total production.

As will be mentioned later, one of the problems of the Defense Program will be to keep up and push vigorously research in the various fields, and in blast furnace practice work may be considered in the use of oxygen to enrich the blast and in ways to lower the moisture in the air and to bring about constant moisture. One company is already obtaining good results in improved quality, reduced coke consumption and increased tonnage by using air reduced to a low and constant moisture percentage.

Iron and Steel Castings—There will be many production problems in the foundry industry, that industry which has been transformed by metallurgists in the last few years. This applies to each of the three major branches, cast iron, malleable cast iron and steel. In each field increased production will be demanded and in each field products will have to be made that have not been among the products of the ordinary foundry. There would seem to be great possibilities in adapting the rapid production methods of foundries to ordnance material of many types, and the metallurgist will find many ways in which the results of the intensive research of recent years can be applied to the new materials that will be demanded. Cast armor of various kinds will be required for many types of equipment and the metallurgist will have to help work out the composition, casting practice and above all the heat treatment that will be necessary.

The newer types of ordinary and alloy cast irons are so wonderful in their properties that they can certainly be applied in many ways not thought of before, and the metallurgist will have to adapt these newer irons and their methods of production to the new demands. This also applies to the newer types of malleable cast iron with equal force.

In regard to steel castings the field is almost unlimited. We now can make steels of almost any composition and can control the analysis and cleanliness of the steels so as to obtain solid clean castings, which after heat treatment give results comparable with forgings. Molding practice, the mixing and treatment of sands and all the factors that enter into the production of good castings are much better understood than formerly so that with proper metallurgical control the results are uniform and good, and reliance can be placed on the product.

While emphasis will naturally be placed on the open-hearth and the electric furnace for producing liquid steel for castings, the small acid lined converter should not be overlooked. Very few are now in operation but when it comes to a matter of rapid tonnage production of steel within its capabilities, nothing can equal the converter and the quality can be made exceedingly good and very uniform. The results obtained steadily over the years at the Boston Navy Yard will repay careful study, and the castings produced find numerous applications. Installation of a converter plant is not expensive nor is much time required and the methods of operation and metallurgical control are well understood.

If there were time and space, more would be said about the heat treatment of castings including cast iron, malleable and steel. This is a field where the metallurgist has shown what he can do and the opportunity for future work is exceedingly wide and the results for the Defense Program will be of great importance.

Rolled Steel—In regard to production of rolled steel the metallurgical engineering problems will be very numerous and only a few of them can be touched upon. Main reliance for steel ingots will of course be placed on the basic open-hearth process, and in order to maintain and increase production and keep up quality the metallurgist will have to study each detail of the process as in the case of the blast furnace. This includes many things, such as the fuel used, the refractories, control of the combustion process, making up the charge, the melting and refining practice and the finishing of the

heats of steel. It extends to the handling of the steel in the ladle and the ingot mold and pouring practice. Here again, fortunately, a great deal of careful research work has been done in the last few years, and the metallurgical engineer will have to draw upon this and apply it to the steel making problems.

The study of the refractories will be particularly valuable. Each extra turn a furnace can be kept in operation will be helpful and this depends to a large extent on the refractories used in the port ends, the walls, the roofs and the checkers. The hearth refractories are of great importance in keeping down delays and we now hardly notice that Austrian magnesite is not available because of the excellent magnesite produced here, and the splendid chromite and dolomite refractories used for hearth work and for patching. The metallurgist will have to study the refractories available and see that they are used to the best advantage. A heat of steel that boils on the bottom is ruined for many applications and care in making up and keeping a good bottom or hearth will be well repaid.

Pouring practice cannot be over-emphasized. In addition to the effect on quality good pouring has a great influence on the yield of usable material obtained in the rolling mill. Good pouring helps bring about good surface on the ingots which reduces chipping and scarfing delays and helps in yield, and good pouring helps greatly in reduction of pipe and the consequent increase in usable material. The metallurgist will find many problems on the pit side of the open-hearth, attention to which will all help in production and quality.

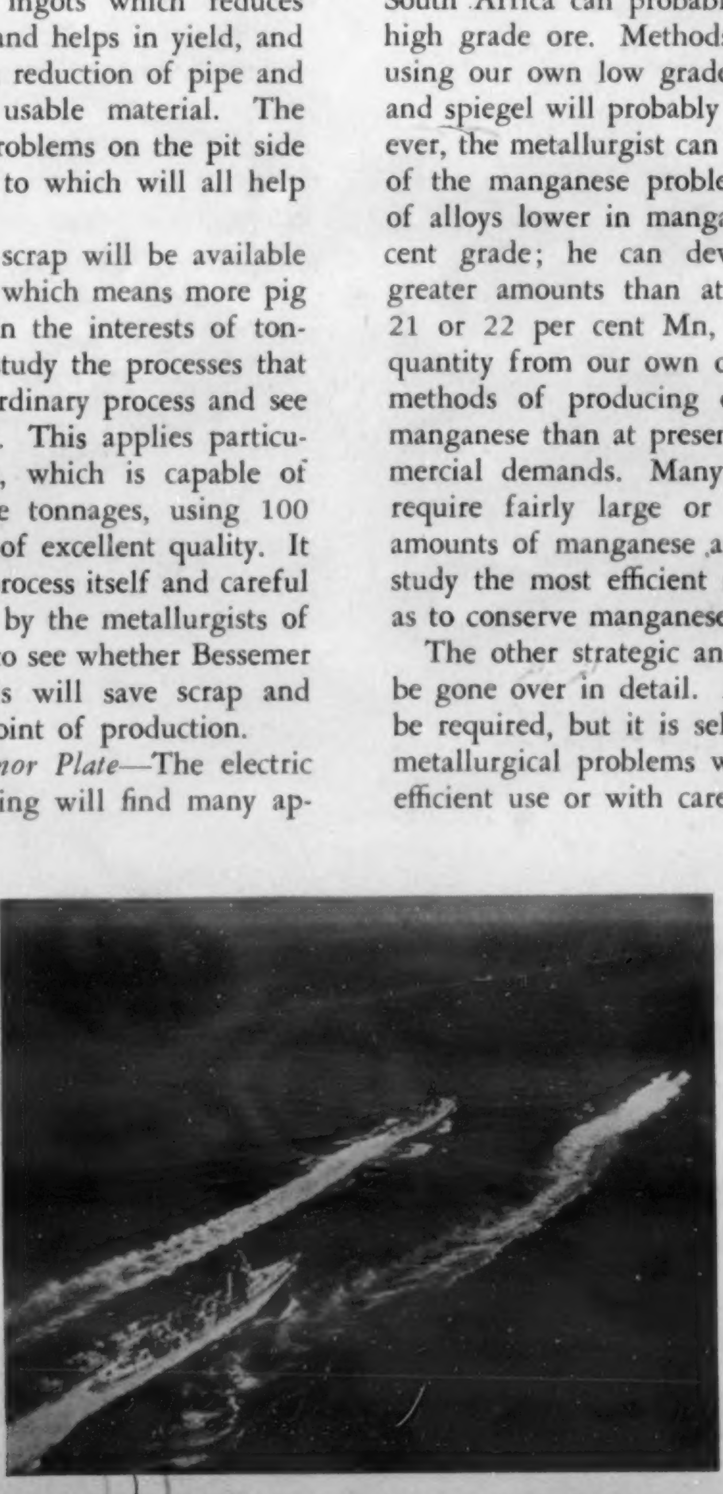
As mentioned before, less scrap will be available for the steel making process, which means more pig iron will have to be used. In the interests of tonnage it may be advisable to study the processes that use more pig iron than the ordinary process and see whether they should be used. This applies particularly to the Duplex Process, which is capable of turning out remarkably large tonnages, using 100 per cent pig iron if desired, of excellent quality. It also applies to the Bessemer process itself and careful examination should be made by the metallurgists of every grade of steel required to see whether Bessemer steel could be applied. This will save scrap and help greatly from the standpoint of production.

Electric Furnaces and Armor Plate—The electric furnace process of steel making will find many applications. One that is clearly indicated is the manufacture of steel for armor plate. Up to now armor plate for ships has been made almost entirely of acid open-hearth steel. It would seem as though electric furnace steel would be eminently suitable for armor plate, and the metallurgical engineers will have to work this out. It is evident the needs for armor plate will greatly increase. Not only does the Defense Program call for a greatly enlarged navy, but tanks, gun carriages and many other pieces of equipment will call for armor plate varying in thickness from less than $\frac{1}{8}$ in. to about 3 in. The production of this material in the tonnages required presents many problems to the metallurgist in regard to steel production, fabrication and heat treatment. Research work has been going on for years but many problems remain unanswered, and the production of the tonnage and quality of bullet proof sheet and armor plate required to meet the immediate and future demands of the Defense Program is one of the most serious confronting the steel industry, and will have to be solved largely by the metallurgists.

Strategic Manganese—Another of the great problems is in regard to the conservation and, in some cases, substitution for the so-called strategic and critical materials. Most important of these from the production standpoint is manganese and so much has been said on the subject that little is necessary here. Fortunately this question has been carefully studied. Sources of supply have been carefully investigated. Brazil and Cuba, the Gold Coast and South Africa can probably supply all our needs for high grade ore. Methods have been developed for using our own low grade ores, and ferromanganese and spiegel will probably be ample in amount. However, the metallurgist can help greatly in the solution of the manganese problem. He can study the use of alloys lower in manganese than standard 80 per cent grade; he can develop methods to use far greater amounts than at present of spiegel up to 21 or 22 per cent Mn, which we can produce in quantity from our own ores, and he can investigate methods of producing ordinary steels with lower manganese than at present which will meet all commercial demands. Many steels that he must make require fairly large or in some cases very large amounts of manganese and for these steels he must study the most efficient methods of manufacture so as to conserve manganese.

The other strategic and critical materials will not be gone over in detail. A good deal of time would be required, but it is self evident that many of the metallurgical problems will be concerned with their efficient use or with careful substitution.

Mention has been made of the yield of good material in the rolling mills. This is a very important matter in regard to tonnage output. Most of the problems connected with yield are metallurgical. One that



is not often considered is soaking pit and heating furnace practice. Careful heating will greatly reduce scale loss which in turn will directly increase yield. As a rule factors which increase yield improve quality so that a study of these factors is of double importance. An increase in yield has a great cumulative effect in regard to tonnage. Under severe conditions of inspection and specifications, such as will be imposed with many of the special and newer steels, the yield of good material at first will be very low, and one of the most important problems for the metallurgist will be to increase this yield and still provide material with the qualities and structures desired.

Inspection—This might not be thought to be a metallurgical problem, but even a rapid consideration of the specifications that will have to be met on the materials called for by the Defense Program will show how many of them are of a metallurgical nature. Steels that have to be subsequently forged all have to pass severe tests covering the internal structure. Some will have to meet grain size requirements. Practically all will have to meet physical test requirements as rolled or after careful heat treatments. All of these call for metallurgical engineering knowledge on the part of the inspectors so that it will be necessary that they are either metallurgists or have had some metallurgical engineering training. Even the most carefully drawn specifications leave something to the judgment of the inspectors, and unless these men can judge the materials presented to them from a metallurgical standpoint, a great deal of excellent and usable material will be rejected. This in turn will lead to the loss of considerable tonnage and will work great harm. A major problem, therefore, is in regard to the proper training of an adequate force of inspectors who can interpret specifications and intelligently apply them to the materials they have to inspect.

The other great metallurgical engineering problem in regard to inspection is to produce material that will conform to the specifications imposed and pass inspection. This of course is not a new problem, but it will be heightened and complicated because of the many new irons and steels needed by the Defense Program, which, as mentioned before, are not usually made by tonnage methods in large plants. The metallurgists will have to go over the specifications in detail, find out how to adjust or modify prevailing plant practice to meet them. In many cases they will have to ask for changes in the specifications leading to conferences, plant experiments on a small or large scale, and the tackling and working out of a great many metallurgical problems. Fortunately plant metallurgists are familiar with work of this kind, and there is no question the problems will be successfully solved.

Consumer Contact—What may be called Consumer Contact will give rise to many metallurgical problems. For instance forging steels of special analysis and properties will be supplied to plants for forging and subsequent heat treatment to be followed by machining in the forging plants or other plants. Much of this practice will be entirely new to the forging plants concerned. There may be entirely new plants organized to meet the needs of the Defense Program. It is evident that metallurgical engineering problems will be very numerous in regard to proper heating of steels, correct forging practice and above all, correct heat treatment practice. All such plants on these and other steels will need well staffed metallurgical departments to control the various steps of the work and to see that the final products meet specifications and are suitable for the work they must perform.

This kind of consumer contact work will prevail in many plants all over the country, and will call for a great many well trained men, and for supervision by men from the plants where the steels were originally produced. Also, there will be many cases of failures of material, as in present practice, which will need metallurgical investigation to show the cause of failure and point the way to change in practice.

This general phase of the subject has been very briefly discussed but it is certain the problems encountered will be very numerous and many men will be needed.

Research—Under Production many other topics could have been discussed. For instance, it is known there will be a great demand for tool steels and special materials used as cutting tools. This will lead to metallurgical engineering problems regarding the adequate supply of tungsten, chromium, cobalt and other materials. Fortunately much thought has been given to the question of tungsten. We have a fair supply in this country, in Mexico and South America, and molybdenum is a satisfactory substitute in some cases. Cobalt seems to be essential for certain cutting alloys and for the wonderful cutting materials such as Carboloy, and an important problem will be the securing of enough cobalt for its essential uses. Also, considerable study has been given to the subject of chromium, so necessary in tool steels and alloy steels. This element is probably the most important alloying element if manganese is excluded. For the present our supplies from Rhodesia and New Caledonia seem assured.

Before closing this brief review of the metallurgical problems which are facing us, attention should be drawn to the importance of continued research work. Great Britain is keeping up, at accelerated pace, the program of metallurgical research laid out several years ago. We must do the same and lay the bases for the advanced practice to come in future years.

Non-Ferrous Metals in the Defense Program

by CHARLES F. LINDSAY

THE USE OF NON-FERROUS METALS and alloys in armament manufacture is widespread and in large amounts. In general, a definite distinction can be made between the direct use of these materials in munitions of war and in contributory uses, such as bearings, springs, etc., in auxiliary machine equipment. A discussion of these contributory uses is so involved that this discussion, on account of time available, will be limited to the direct uses of non-ferrous metals and alloys in the production of arms and other materials of war.

In order to make this discussion clearer, I am dividing these materials into four distinct classifications:

1. Copper and its alloys.
2. Nickel and its alloys.
3. Lead and its alloys.
4. Aluminum and its alloys.

Copper and Its Alloys

Of these four, copper and its alloys are unquestionably the most important. The largest use of copper and its alloys is in all probability in the manufacture of so-called cartridge brasses. This brass has an average composition of 70 per cent Cu, 30 per cent Zn. The chemical specifications allow a variation of 1.5 per cent in copper content plus or minus the mean, and demand that impurities, iron and lead, be kept to a minimum and must not exceed 0.05 per cent. The physical requirements of this brass, in order to insure maximum production and ease of handling, include:

1—That the composition shall be closely held, in order that the metal shall be completely and wholly in the alpha phase at all temperatures.
2—That it be rolled to close limits of thickness.
3—That it be free from any inclusions, piping and surface faults, such as scabs, cold shuts, etc.
4—That it be annealed to furnish a uniform grain structure of maximum ductility.

This brass is used in the manufacture of cases for all small arms ammunition and in addition machine gun and rapid fire cases in all fixed ammunition up to and including 6-in. rapid fire guns.

Small Arms Ammunition—For the manufacture of 0.30 calibre rifle ammunition a requirement of 44.02 lbs. gross of this material is required per 1000 lbs. To this must be added a small amount not exceeding 10 per cent, or approximately 4 lbs. per 1000, for use in the manufacture of primer cups, and anvils. The 0.50 calibre cartridge case requires 196 lbs. gross weight of cartridge brass per thousand, to which there must be added the same amount for primers and anvils bringing the total up to approximately 200 lbs. gross of brass for cartridge cases.

The next item in the production under discussion is the 0.45 automatic pistol ammunition, which requires 21.77 lbs. gross of cartridge brass, with a similar amount added for primers and anvils, making a total demand of brass per case of approximately 25 lbs. per 1000.

The above covers what is commonly known as small arms ammunition. In addition there must be added the requirements for larger cases, including 20 m.m. cases, one pounder cases, 75 m.m. cases and 4, 5, and 6-in. rapid fire Navy cases. The 20 m.m. cases require 0.03 lbs. per 1000. The 37 m.m. cases require 1.2 lbs., and the 75 m.m. require 3 lbs., and the 4, 5, and 6-in. rapid fire Navy cases require 14 lbs., which are all made from the same blank.

To these figures which represent the weights of brass blank must be added an approximate $33\frac{1}{3}$ per cent to cover skeleton trimmings, etc., in order to obtain the gross weight of brass needed per case giving us the following values:

Case	*Gross wt. brass per M cases*
20 m.m.	400 lbs.
37 m.m.	1600 "
75 m.m.	3800 "
4 in.	All made from same blank
5 "	18660 lbs.
6 "	

At the present time it is impossible to give even an approximate figure of the number of rounds in the above classification that will be demanded in the preparation program by the Government per day, and therefore it is impossible to give even an approximation on the production demand on the brass and ammunition industries.

During the last World War, the production of these types of munitions increased very rapidly until they had reached the staggering figure of almost 4,000,000,000 rounds of small arms ammunition per month or in excess of 130,000,000 rounds per working day. This was, of course, at a time when the country was actively at war and the production was being used up continuously and almost as fast as it was produced. At the present time I do not believe that there is any chance of the requirements even approaching these figures and would not hazard

a guess as to the demand in the near future.

Gilding Metal—Added to the above is the requirement of gilding metal for bullet jackets. Gilding metal for bullet jackets is a copper-zinc alloy of approximately 90 per cent Cu, 10 per cent Zn. During the last war these bullet jackets were almost entirely made of cupro-nickel, but this material has now been superseded by gilding. The bullets for 0.30 Springfield rifle and 0.50 calibre are of four types: regular, armor piercing, tracer and incendiary. The bullet jacket metal requirements vary slightly between these four types, but an average figure will be approximately 14 lbs. per 1000. For the 0.50 calibre cartridge case the bullet jacket requires approximately 93½ lbs. of gilding and the United States Government 0.45 automatic pistol ammunition requires 7.6 lbs., per 1000.

The following short tabulation shows the requirements for case and bullet jackets of these three sizes of small arms ammunition in pounds per thousand:

		0.30 Cal.	*0.50 Cal.*	*0.45 Cal.*
Cases	Copper	33.6	140	16.8
	Zinc	14.4	60	7.2
Bullet-Jackets	Copper	12.6	84.15	6.849
	Zinc	1.4	9.35	.761
Totals Metal		62.0	293.50	31.610

Bullet requirements in non-ferrous metal jackets do not enter into the larger sizes which are steel projectiles with copper driving bands.

Cadmium-Free Spelter—At the beginning of the last war it was the general belief among government and manufacturing authorities that the spelter used in cartridge brass manufacture must be cadmium free. An immediate price differential of many cents per pound was created in favor of cadmium-free spelter. Tests, conducted by the writer in 1914 proved conclusively that this was a fallacy; 75 m.m. cases were made which withstood reloading on the proving ground 80 times, and more might have been added had re-necking facilities been available.

With the very large, well organized, and cooperative brass industry largely centered in Connecticut

and with its record through 1914 to 1918, there seems to be no ground for doubt that this industry, together with U. S. arsenal production, can readily take care of any present demands from Washington.

Fuses—The next large demand for copper and its alloys is in the manufacture of fuses. The U. S. Government specification for fuse rod used in this manufacture is:

	Permitted	*Desired*
Copper	58.5–61.5	60
Lead	1.5– 2.25	2
Iron	0– 0.15	—
Tin	0– 0.15	—
Nickel	0– 0.15	—
Zinc	Balance	38

The weight of metal used per fuse naturally varies, but assuming the 21-second fuse, as now being manufactured, as an average, the gross weight of rod per fuse is approximately 5 lbs. Again the fact that fuse parts are now in part being made from aluminum introduces another variable.

Again it is impossible to give accurate figures for the required production, but again it will be temporarily, at least, much less than the 1918 requirements.

Driving Rings—The next use to be touched on is the demand for copper driving rings for shrapnel and shell. This is a demand for pure copper in the form of rings, which are fitted into grooves in the shell and serve two purposes:

1—Sealing off the powder fumes, and
2—Providing a soft metal contact between the shell and the rifling of the gun.

There are three methods of producing these rings which are in common use:

(a) The rolling of the tubing into lengths of the proper diameter inside and out and which are then cut into rings of the proper height.
(b) The piercing of the billets and thereafter drawing to finished dimensions and thereafter cutting into rings and
(c) By blanking, cupping, and drawing the copper into required form.

To provide an accurate average figure of driving ring requirements would require the development of values for all size of shells from 20 m.m. to 18 in. together with figures of the proportionate number made in each size. This is, at the present time manifestly impractical.

The same restriction on being able to give any accurate demand or quota for these rings holds as in the previous discussion.

The above covers in general the principal direct demands on the brass and ammunition industries for copper and copper alloys in the manufacture of munitions.

Nickel and Its Alloys

As pointed out, during the previous war all bullet jackets were made of cupro-nickel. This has all been superseded and substituted by gilding metal, therefore with the exception of small amounts of nickel used in plating primers, the direct use of nickel in ammunition manufacture has almost disappeared as far as non-ferrous alloys are concerned.

There is, of course, a very large and very important demand for nickel in the manufacture of special steels, but this can and should be handled as part of the ferrous alloy discussion and is hence disregarded in this.

Lead and Its Alloys

The uses of lead and its alloys in the manufacture of munitions depends largely on its weight characteristic, plus its easy casting and forming ability. The slug for a 0.30 calibre bullet, regular type weighs 111 grams each, with a composition of 90 per cent Pb, 10 per cent Sb, or approximately 16 lbs. of this alloy per thousand. The 0.50 calibre bullet slug will vary for different types ranging from 64 grs. for the armor piercing bullet and 207 grs. for the tracer bullet, or between 9 and 30 lbs. of metal per thousand slugs. The 0.45 calibre automatic pistol bullet has a core weighing 196 grs. of pure lead or 28 lbs. per thousand.

Again the same restriction holds in an attempt to interpret these figures into expected demands, both in view of the present condition of the industry and its previous record. There is again, in my mind, no question of the industry's being able to meet expected requirements.

A further large use of lead in munition manufacture is in the production of shrapnel ball. During the last war when large bodies of troops were in close contact and massed, the use of shrapnel in spraying troops with heavy slugs, was very large.

Judging from the course of the present war the use of shrapnel is likely very much less than the last world war and no fear need be felt in regard to the industry's being capable of taking care of all requirements.

Aluminum and Its Alloys

In recent years there has been a substitution effected by the use of aluminum in fuses, replacing part of the demand on copper and its alloys. The amount of this above substitution is impossible to estimate.

Of course, at the present time, the largest demand on aluminum is in the airplane industry, both in engine parts, for propellors and for fuselage. For engine manufacture and taking into account the present size of military airplane engines, it is believed that approximately 1000 lbs. of aluminum is supplied to the engine manufacturer per engine. This figure does not represent the actual weight of the metal in the airplane, but approximately represents the weight supplied by the aluminum manu-

facturer to the engine maker and includes machine and other losses in fabrication. A further use is in propellors and can be roughly estimated as 200 lbs. per propellor where equipment propellors are used. I am not attempting any discussion of the amount of aluminum used in body construction for many reasons. Among these are the following:

It varies tremendously with the type of plane being constructed, whether pursuit, fighter, bomber, or transport and again because it varies greatly with the make. The reader is in the position of being able to apply a marketability factor to the above figures as accurate as any guess that the writer could make.

Inasmuch as the sources of raw materials—bauxite and cryolite for this industry—are almost wholly outside the United States territory the capability of the aluminum industry to meet demands on it would seem, therefore, largely to depend on the keeping open of its lines of supply.

There are, of course, innumerable miscellaneous uses of non-ferrous metals in the armament industry. Among these may be listed, if not discussed, the use of magnesium in aluminum alloys and in tracer bullets where a mixture of magnesium, and barium peroxide in a special capsule is used. The use of aluminum powder in the manufacture of incendiary bombs and the use of phosphorous combines in the manufacture of incendiary bullets. The use of mercury in the manufacture of fulminate of mercury.

Acknowledgment

The writer is greatly indebted to Remington Arms Co. Inc., Bridgeport Brass Co., Scovill Mfg. Co., and Aluminum Castings Co., for part of the data used in this discussion.

REVIEW OF THE STRATEGIC METALS

A strategic material is classed as one which is not available in the United States in sufficient quantity to meet the needs of a rearmament program—large quantities must be imported. Such materials may even be regarded as strategic even in peace times, the cutting off of a supply of any of them interfering decidedly with domestic manufacture and needs.

Of the many metals and their alloys which are considered as strategic in the military or preparedness sense, the following seven are prominent:

Manganese	Tungsten
Chromium	Antimony
Nickel	Tin
Mercury	

The importance of most or all of these materials is so definitely great that the present preparedness and defense program of the U. S. Government would fail if the supplies of at least some of them should be interfered with. We are dependent in large degree on importations.

To clarify the present general situation as to these seven metals, we present on the following pages a series of reviews, written, whenever possible, by men of authority in those fields. It should be said that some difficulty has been experienced in obtaining these statements due to the relations of certain companies and men to the Defense Program. In one case it has been necessary for this office to supply a discussion on nickel.

The relation of these strategic metals to any military preparedness program, together with the authors of the reviews, are briefly summarized as follows:

MANGANESE: *This metal is essential to all steel making operations—no steel of any kind can be made without manganese. We are dependent on importations for the major portion of our consumption. Thus far no substitutes, at least on any large scale, have been found. Martin Gentry, assistant to the president, Cuban-American Manganese Corp., New York, contributes this discussion.*

CHROMIUM: *This element is essential in many of the important high grade steels used in military equipment of all types—armor plate, stainless and heat-resisting steels, aircraft steels, and others. The preparedness program would be seriously crippled without its availability. S. H. Dolbear, of Wright, Dolbear & Co., 17 Battery Place, N. Y., is the authority on this material.*

NICKEL: *The place of nickel in a defense program is analogous to chromium.*

TUNGSTEN: *The many complex machining operations involved in producing munitions and military equipment of all kinds is dependent to a large extent on the metal tungsten—in high-speed steels and some of the carbide tools. It enters into other important alloy steels. Molybdenum is a reliable substitute in some cases and there are other carbide cutting materials. Dr. Colin G. Fink, professor of Electrometallurgy, Columbia Univ., New York, is the contributor—Chairman, Tungsten Committee, U. S. Munitions Board.*

ANTIMONY: *A large use of antimony is in storage batteries which are more than ever essential to any large scale mechanized military equipment program. And there are other uses. G. A. Roush, editor of "Mineral Industry," reviews this subject.*

TIN: *This metal is a large factor in the military use of bearings, solder and tin cans. Direct substitutes are lacking, though there are partial ones. Dr. C. L. Mantell, consulting chemical engineer, New York, author of "Tin," authoritatively writes this discussion.*

MERCURY: *The principal military use of this metal is a fulminate as a detonator. It is also a factor in anti-fouling paint for naval use. C. S. Wehrly, of the Merchants Chemical Co., New York, is the contributor.*

Manganese

by M. B. GENTRY

The present situation of the United States in relation to manganese is marked by important steps that are being taken toward decreasing the nation's dependence upon distant foreign sources for its future supplies of this highly essential strategic material.

A large new plant is being built in Montana to concentrate domestic manganese ore, an existing plant in nearby Cuba is being expanded, and the government in its national defense program is moving to build up reserve stockpiles and to encourage the development of deposits within our continental boundaries.

Why Strategic—In reviewing the current manganese situation, it is advisable to consider first the broader aspects of the problem. Why is manganese a strategic material? How is it used? What countries are the major producers? What percentage of consumption is supplied by domestic production?

Manganese is ranked by many authorities as the United States' No. 1 strategic material. It is required as a deoxidizer and desulphurizer in the manufacture of every ton of steel, helping to produce a clean, sound metal. Approximately 14 lbs. of manganese, it is estimated, are used in making one ton of steel.

The mineral is ordinarily consumed by the steel industry in the form of ferromanganese, an alloy containing approximately 80 per cent metallic manganese and the remainder mainly iron and carbon. Ferromanganese is produced from ore containing approximately 48 per cent manganese but preferably more. No substitute for ferromanganese in steel making has ever been successfully developed.

A manganese shortage in time of emergency would constitute, therefore, a dangerous bottleneck curtailing the output of steel—not only for armor plate, tanks, guns and other military weapons but also for the less direct requirements of national defense, the bridges, trucks, trains, buildings, machinery.

Imports—Against this background of manganese indispensability, the United States in the period since the World War has been forced to import more than nine-tenths of its consumption of ferrograde ore. The great bulk of this ore has come from such far-off sources as Russia, leading world producer, India and the African Gold Coast.

In 1937-1939, the United States imported for consumption an average of about 674,000 tons a year of its estimated average annual consumption of 705,000 tons.

Russia, which in some years has supplied as much as half of total imports, accounted for approximately 34 per cent of the imports in that 3-yr. period. The African Gold Coast sent 31, Cuba 18, India 9, and Brazil 7.5 per cent. Recently, South Africa has become a substantial supplier.

Shipments from nearly all these sources upon which the United States has relied in the past are extremely vulnerable to attack on the seas. Ore-loaded ships, for the most part, must cross long stretches of unprotected waters and, in the event we were engaged in war, would be menaced by submarines and bombing planes.

Russian manganese, shipped to America from the Black Sea port of Poti, must travel across 5,700 miles of the Mediterranean and the Atlantic to reach Baltimore. India is 10,000 miles from Baltimore, South Africa 7,000, and the Gold Coast 4,900.

Brazil, which during the 1914-18 World War developed into the United States' foremost source, is a somewhat safer source, but in wartime, shipments even from that South American country would be vulnerable to attack, as the record of that first World War proves. Present rail facilities for transporting ore from mine to coast, furthermore, are inadequate to handle the greatly-expanded production that would be necessary if the United States sought to replace other imports with Brazilian manganese.

In the last analysis, thus, the United States in an extreme emergency could count only on domestic production and such relatively safe nearby sources as Cuba, which at the nearest point is only 90 miles off the coast of Florida.

American and Cuban Supplies.—During the first World War, Cuba supplied a portion of the United States' requirements and after the war, shipped small amounts, mainly from small high-grade deposits. In 1930, the Cuban-American Manganese Corp. undertook the development of low-grade Cuban ores. The company succeeded in developing a flotation process that, for the first time, could be applied to oxide manganese ores.

With the successful concentration there of ores of less than 20 per cent Mn to a grade of 50 per cent and better, Cuba during the past 3 yrs. was one of the United States' three leading manganese suppliers. The Cuban-American company is now expanding its plant by approximately one-third to provide a capacity of 130,000 tons annually by Jan. 1, 1941.

The United States has widely-scattered low grade deposits of a grade similar to those of Cuba, but domestic production, as has been noted, has supplied less than a tenth of the nation's ferrograde ore consumption since 1918. The grave emergency that year, when imports had dwindled and continued steel production was threatened, pushed domestic production to a peak of 311,000 tons, about 35 per cent of consumption.

During 1937-38-39, domestic production averaged

about 31,000 tons annually, slightly under 5 per cent of the estimated consumption. This domestic picture is brightened considerably, however, by the recent announcement of the Anaconda Copper Mining Co. of plans to construct a 100,000-ton concentration plant at Butte, Mont. The plant is expected to be completed early in 1941.

The total capacity of both the finished Cuban-American and Anaconda plants does not, of course, come anywhere near equalling the total manganese requirements of the United States even during peacetime, but it does represent an important advance toward freeing the nation from dependence upon distant sources, an advance that had not been made prior to our entry into the first World War.

Stockpiles—Another step in manganese procurement that had not been taken before April 6, 1917, is the purchase by the U. S. Government of ore for stockpile purposes. This program was inaugurated late last year when the procurement division of the Treasury Department purchased the first 25,000 tons from Cuba. In all, the division has purchased 86,500 tons, and most of this is believed to have been delivered.

Subsequently, the Metals Reserve Co. was formed as a branch of the Reconstruction Finance Corp. to acquire manganese and tin. Contracts for 562,000 tons of manganese ore, including deliveries to be made over the next 3 yrs. by Cuban-American and Anaconda, have been announced.

To the growing government stockpile must be added the reserves of private industry. On Sept. 1, stocks in bonded warehouses totaled approximately 850,000 tons, despite unusually heavy withdrawals during August.

Electrolytic Manganese—Another factor to be taken into consideration in studying the manganese future is the electrolytic process which has been investigated by the U. S. Bureau of Mines. This process, which produces pure manganese (better than 99 per cent manganese) from low grade domestic ores, is still in the experimental stage, but a plant erected in Knoxville, Tenn., by the Electro-Manganese Corp. has been turning out about 1500 lbs. a day.

Even with all these favorable developments, the United States' manganese problem is still a serious one. At a steel production rate of 90 per cent of capacity, a rate that was being exceeded in early September, the nation needs an estimated 850,000 tons of ferrograde ore a year. Existing domestic and Cuban production facilities and those under construction can supply but a part of that.

This production plus the reserves now on hand would give the nation a breathing spell of well over a year, however, in which to investigate and to develop the indicated avenues that lie ahead for meeting our manganese needs.

Chromium

by SAMUEL H. DOLBEAR

Chromite is classed as a "strategic" mineral. Insofar as the United States is concerned, this is only correct in part.

The problem should be considered from the viewpoint of consumption by three industries, i.e., metallurgical, chemical, and refractory. In terms of ore, without regard to its chromium content, consumption is distributed about as follows:

Metallurgical	50 per cent
Chemical	20 per cent
Refractory	20 per cent
Miscellaneous	10 per cent

Insofar as ores which can be used in the manufacture of high grade ferrochromium are concerned, the strategic classification is correct. In the manufacture of chemicals, the controlling factor is one of economics which in normal times has led to the use chiefly of ores containing 44 to 46 per cent chromic oxide.

If technical practice had not advanced beyond that of 1918, ores for refractory purposes could, at a price, be produced in the United States in sufficient quantity to supply the trade.

Sources of Supply—Disregarding Russian output, published figures of which must regarded with doubt, the most important sources of chromite in recent years have been Turkey, Southern Rhodesia, New Caledonia, South Africa, Yugoslavia, Cuba, Greece, and the Philippines.

Unfortunately figures of production do not differentiate between ores of various grades. Ores from certain of these countries are entirely unsuited to metallurgical use, and in some cases are too low grade to be used for economic production of chromium chemicals.

Metallurgical Ore—The steel industry in the United States is dependent on the use of 70 per cent grade ferrochromium. This requires ore containing at least 48 per cent chromic oxide, and a chrome-iron (metallic) ratio of not less than 3:1. Any change from this basis would have its effect on efficiency in the industry.

In Great Britain steel mills use ferrochromium of a chromium content of 60 to 65 per cent. Such alloy may be made from ore of a chrome-iron (metallic) ratio of 2.5:1.

Upon the exhaustion of stocks and inability to obtain fresh supplies of high grade ore, American steel mills may need to adopt the British standard. Chief sources of metallurgical ore are Turkey, Southern Rhodesia, New Caledonia, and India. Closing of the Mediterranean has cut off Turkish shipments at present.

Stocks of high grade ore in private hands are the largest in the history of the industry.

Specifications for metallurgical ore ordinarily call for a minimum of 48 per cent Cr_2O_3; iron (metallic) in an amount not to exceed one-third of the chromium (metallic); and silica not over 8 per cent. There is, however, in industry no rigid insistence on these specifications, which may vary somewhat from these figures. Government specifications heretofore have been limited to lump ore containing not over 10 per cent of fines which will pass a ½-in. mesh screen.

Lump ore is preferable in the manufacture of ferrochromium although concentrates and fines are also used.

Chemical Ores—Because it is more economical to do so, ore containing around 46 per cent Cr_2O_3 is ordinarily used in the manufacture of chemicals. While a limit is sometimes placed on the silica content, its presence in greater or less degree has little effect on the value of the ore. Domestic production of lower grades could conceivably supply the chemical industry, but would increase costs and reduce plant capacity. The "strategic" importance of chemical ores is, therefore, less than that of metallurgical ores. The chief source of chemical ore is Transvaal, with lesser amounts derived from Greece, Yugoslavia, the Philippines, New Caledonia, and some other countries.

Refractory Ores—In recent years the chief sources of these ores have been the Philippines and Cuba, with lesser amounts from Greece. The ore sought for the purpose is of such a chemical character as to produce, on heating, a chrome spinel. Philippine ore ordinarily contains:

Cr_2O_3	(minimum)	32 per cent
Fe	(maximum)	11 per cent
Al_2O_3	(minimum)	25 per cent
SiO_2	(maximum)	5 per cent

Philippine reserves are estimated at 8,000,000 tons or more. Some Cuban ores are of similar composition; reserves, while substantial, are smaller than those of the Philippines. The presence of a higher chromium content does not usually affect the price.

Domestic Situation—In recent years mines within the United States have yielded only a few hundred tons annually. This has been chiefly used on the Pacific Coast. That domestic deposits are capable of expansion is shown by the history of operations in the 1916 to 1918 period. Prices during those years ranged as high as $1.00 to $1.25 per unit of 1 per cent Cr_2O_3 per short ton, f.o.b. mines. In 1918, the highest year of record, production exceeded 80,000 net tons. In California and Oregon many deposits near rail were exhausted and before the end of the war ore was being hauled 50 miles or more to shipping points. This would tend to decrease any further production rate. On the other hand, roads have been substantially extended during the intervening years, and the cost of truck operation substantially reduced.

Large low grade deposits have been opened up in Montana by the U. S. Bureau of Mines and the Geological Survey. Their chromium-iron ratio is around 1.6:1 which makes them unsuitable for metallurgical use by established methods. Research by the Bureau of Mines and by private agencies has been directed toward some plan to utilize this ore. Until such work has been carried further, it cannot safely be relied upon as a factor in national security.

Domestic deposits have yielded small tonnages of metallurgical ore in the past. Deposits in Alaska and Washington may yield larger amounts if they are developed and equipped but, so far as exploration has gone, do not indicate the presence of tonnages sufficient to supply the industry over any protracted period.

Some deposits in the Pacific Coast area are capable of yielding substantial tonnages of milling ore which can be beneficiated to yield high grade concentrates. These are probably more important potential sources of domestic supplies at present than low grade deposits of Montana and other places which do not respond to this treatment.

Summary—A large part of the chromite supply of the United States in recent years has come from deposits controlled by belligerents in the present war. In most cases long ocean hauls are involved. Supplies from Turkey and other Mediterranean sources have been decreased by military operation in that region. Other sources at present available may be threatened by further military developments.

Fortunately consumers' stocks in the United States are large. These have been supplemented to some extent by government stockpile purchases. Domestic mines cannot be considered as a readily available reserve in case of emergency. During the World War about 2 yrs. was required to bring about substantial production.

In the case of extreme emergency industry can be adjusted to use ores of somewhat lower grade, but at increased cost of production and at decreased efficiency of operation.

Nickel

by EDWIN F. CONE

Nickel has been classed as a strategic metal because, of the total American consumption, an insignificant amount is obtained in this country. The great bulk comes from Canada. That this metal is essential to any military program is self-evident.

As the war has progressed, nickel has become the least strategic of all the seven metals. This is due to the formation of the cooperative defense commission between Canada and the United States. This practically insures ample supplies for the duration of the war—unless the fortunes of the British Empire turn out more disastrously than is at all probable.

Importance—It is stated by one authority that "next to manganese, nickel is probably the most important metal in the development of a modern munitions program, and it is one of the few for which the country is practically entirely dependent on outside sources for its supply; there is no direct production of nickel in the United States, such small output as does exist (a few hundred tons a year) being a by-product of the electrolytic refining of copper."

Some regard chromium as equally important, or more so than nickel. "But without nickel and chromium," says another authority who classes tungsten with these two metals, "no battleships and no guns; without chromium and tungsten, no tools for the efficient fabrication of the countless parts and products that enter into modern armament."

Requirements—The consumption of nickel has expanded rapidly, due in part to new uses, developed largely by the International Nickel Co., through research. In 1913 the world output was 32,700 metric tons, increasing to 47,900 tons in 1918. After declining during the first war depression, it rose to 57,000 tons in 1929 and then, after further declines to 20,000 tons in 1932, it advanced to 113,000 tons in 1937. Consumption in this country in 1937 was 45,900 net tons. A reliable estimate of the quantity to be used in our preparedness program is not available.

Metallurgical Uses—The use of nickel enters into many ferrous and non-ferrous products, most of which have military significance—alloy steels of many types; alloy cast steels; alloy cast irons, low, medium and high nickel; stainless steels of many kinds; non-magnetic and highly magnetic alloys; nickel silver, nickel bronzes, nickel brasses, copper-nickel alloys, nickel-aluminum alloys, malleable nickel, and so on.

Many of the military uses are identical with the ordinary industrial uses, but in addition to these, there are many strictly military uses.

In the Airplane—The importance of the airplane in war has been the one outstanding demonstration in the present European hostilities. Nickel, as well as aluminum, is essential. Quoting from a recent statement of President R. C. Stanley of the International Nickel Co.:

> Nickel steels and nickel alloys are widely used in airplane engines and this use exemplifies the diversified and exacting conditions for which these nickel-bearing metals are specified. Metallurgists have been able to provide materials which permit design changes and the use of improved fuels. Thus there has been developed the present highly efficient power unit which weighs approximately one pound per horse power generated. Nickel steels with high fatigue resistance; nickel-aluminum alloys with increased tensile strength; nickel-chromium, resistant to the attack of exhaust gases; and other alloys of high nickel content, which stand up in the combustion chambers, have all contributed to this advance.

Substitutes—The problem of substitutes for any strategic metal is important—particularly manganese. Very few, if any, substitutes for nickel have been developed—they have not been needed due partly to the cheapness of the metal and the newness of the developments of its uses, and also because many of the uses of nickel are themselves substitutes for some other metal or alloy.

Germany has very limited supplies of nickel but in her armament program one substitute, particularly in stainless steels and other high nickel materials, has been manganese. Other substitutes used are not known.

Gilding metal, a special type of brass, instead of cupro-nickel for bullet jackets has been developed and other alloy steels might displace certain ones containing nickel.

Vital as nickel is to any military preparedness program, American industry is not likely to be in want of supplies nor in need of substitutes.

Tungsten

by COLIN G. FINK

Tungsten has been a strategic metal in most countries ever since the introduction of tungsten steels and tungsten alloy tools.

Cutting Tools—Tungsten tools cut a hundred times faster than the old carbon steel tools and tungsten alloys are among the very toughest alloys used for instruments of offense as well as defense. Some essential properties of tungsten steels have been known for over 75 yrs. Self hardening steel tools were invented by Robert Mushet between 1860 and 1870. But not until the Paris Exposition of 1900 did the modern era in tool steels begin. At that time, Frederick W. Taylor of Philadelphia first exhibited to the astonished gaze of incredulous machinists and metallurgists the spectacle of a tool cutting so fast and so deep that it delivered steel chips at a blue heat and in amazing quantities. A few years after this exhibition, Ellwood Haynes of Kokomo, Ind., introduced the cobalt-tungsten-chrome alloys, universally known today as the stellite high-speed tool alloys. A familiar stellite composition is 10 to 15 per cent W, 45 to 52 per cent Co, and 28 to 32 per cent Cr. A familiar Taylor steel composition is 18 per cent W, 4 per cent Cr, and 1 per cent V.

A few years ago, a third type of tungsten tool was introduced into industry, namely, tungsten carbide, usually cobalt-cemented and a product of powder metallurgy. This product is so hard that it has replaced the more expensive diamond in many applications. It is much harder than but not as tough as the Taylor or stellite tungsten alloys.

Occurrence—Tungsten occurs in nature predominantly as the tungstate of iron, mineralogically designated as ferberite; and the tungstate of calcium, scheelite. Less frequent is the occurrence as such of the tungstate of manganese, hübnerite. As a rule, hübnerite is associated with ferberite, the latter usually predominating in the so called mineral "wolframite," the iron-manganese tungstate. The steel industry, which consumes over 90 per cent of the world's tungsten, prefers, as starting material, the 80 per cent W ferroalloy which must be practically free from deleterious impurities such as tin and arsenic, frequently found in tungsten ores. A big boom to the tungsten steel industry was the commercialization of the electric arc furnace. Tungsten is the highest melting of all metals (3360°C.) and no fuel fired furnace can even approach this temperature. The melting point of pure 80 per cent ferrotungsten is 1640 deg C.

The economically important tungsten ore localities are almost all situated in that great horse-shoe-shaped chain of mountains bordering on the Pacific Ocean and extending from the southern end of Malaysia north through Alaska and south through Canada and the United States, Mexico and South America (Andes). By far the largest producer of tungsten ore for the past 20 yrs. has been China. Here the mineral is primarily wolframite and, although mining methods are relatively simple and crude, mining and transportation costs are the lowest of any. They are about 1/5 or 1/6 of the cost of mining tungsten in the United States.

Domestic Tungsten—Before the advent of China in the tungsten market, Burma and the United States contended for supremacy as the largest world producer. But with the receipt at San Francisco of Chinese wolframite concentrates, selling at a profit, at \$1.50 and \$2.00 per unit, the United States tungsten industry virtually collapsed. And it required a protective tariff to partially resuscitate it. The U. S. Bureau of Mines in a recent report states that although "tungsten may be considered as a first priority strategic mineral, the position of the United States in this commodity is less severe than in the case of manganese, tin and chromium." For a number of years past, Nevada has been the largest tungsten producing state. The total United States production in 1939 amounted to 3900 metric tons of 60 per cent WO_3 concentrates as compared with a total consumption of 4750 metric tons and a world's tungsten production of 40,000 tons.

Just as cheap Chinese tungsten ore crippled temporarily the tungsten mining industry of the United States, so likewise was the reaction in other tungsten centers such as British India, Bolivia, Argentina, Spain and Portugal. (The Iberian peninsula is the only large, significant source of tungsten in Europe.) And while these countries were engaged in re-establishing the lost source of revenue, Germany at once encouraged further development of tungsten ore production in China, placed no restriction on its importation and for almost 10 yrs. before this present world conflict started, piled up a vast tungsten ore pile in Germany far in excess of peacetime requirements and sufficient in quantity, as variously estimated, to supply her for six more war years to come, assuming no further importations.

Conclusion—Fortunately, our own tungsten resources comprise high-grade deposits usually free from deleterious impurities. And we feel certain that in an emergency the output of Nevada, Colorado, California and of other states can be increased many fold. Furthermore, tungsten's sister metal, molybdenum, can be substituted, in part at least, for tungsten in many important steels. And the United States has the largest molybdenum mine in the world, supplying over 85 per cent of the world's requirements.

Also, radical advancements have been made in tool design as to economies in tungsten (and cost) so

that only the cutting edge, but not the shank, is made of tungsten steel or stellite.

And finally, the magnet alloy industry has been completely revolutionized during recent years. The permanent magnet steel carrying 4 per cent tungsten has been surpassed in quality and performance by the aluminum-nickel-cobalt alloys.

Nevertheless, when peace comes, it will be the tungsten alloys and their manifold applications that will be foremost in hastening the return of normal pursuits.

Antimony

by G. A. ROUSH

The commercial and strategic aspects of antimony have been radically altered during the past decade, largely through the establishment in 1931 of a domestic smelting plant using Mexican ores; a second factor of importance has been the growing demand for antimony compounds, especially the oxide, which is used as a pigment in fusible enamels and nitrocellulose lacquers.

Between these two factors a wholly new set-up has developed in the domestic situation. The antimony supply of the United States in 1929 was quite typical of that of the years preceding, and may well serve as an example of the status just preceding the establishment of the domestic smelting industry and the disturbances resulting from the prolonged industrial depression. During the past 25 yrs. antimony consumption in the United States has absorbed from one-third to two-thirds and has averaged somewhat under one-half of the world output of new metal. Consumption in 1939 recovered from the 1938 recession, and while some of the final data are still lacking, those at hand indicate a general level about the same as in 1937, which may then be taken as representative of conditions in 1939, for comparison with 1929. This comparison brings out some interesting and pertinent points.

Domestic Smelting—The first smelter went into operation at Laredo, Texas, in 1931, using Mexican ores, and until 1938 this was the only plant in operation, aside from the long-established output of hard lead, some of which was from domestic and some from foreign ores. In 1938 a plant in Los Angeles began the treatment of antimony-mercury concentrates imported from Mexico; thus far this plant has operated only on a small scale, apparently about 200 tons of antimony a year. During 1940 another small plant is expected to go into production at Kellogg, Idaho, to treat antimony-bearing ores of the Coeur d'Alene region.

Sources of Supply—In 1929 the total apparent consumption of antimony in the United States was about 30,000 net tons. Following the heavy slump during the depression, with a low of 12,150 tons in 1932, consumption recovered to 26,200 tons in 1937, but the type of consumption and the sources of supply had been radically altered, as may be seen from the following table of comparison of antimony consumed in the United States.

	1929 Short Tons	Per-cent	1937 Short Tons	Per-cent
In crude imported	1,350	4.5	580	2.2
Metal imported	10,560	35.2	610	2.3
In alloys imported	300	1.0	410	1.6
Smelter output, metal	None		4,060	15.5
Smelter output, alloys	3,050	10.1	1,640	6.2
Secondary metal recovery	11,130	37.1	12,340	47.1
In compounds, domestic and imported	3,650	12.1	6,560	25.0
Total	30,040		26,200	

As a result of the establishment of domestic smelting, imports of metal have almost disappeared, and have been replaced by ore imports. This shift naturally made a corresponding shift in the sources of supply, as shown in the following tabulation of the percentage distribution of the total imports since 1915, dividing the time into three periods: The first, 1915-1930, previous to domestic smelting; the second, 1931-1935, covering the years required to put the smelting industry on an established basis; and the third, 1936-1939, covering subsequent years to date. The sources of antimony imports into the United States:

Imported from:	1915-1930	1931-1935	1936-1939
China	75.8	43.4	6.0
Mexico	8.1	48.0	62.2
South America	7.0	7.3	29.6
Others	9.1	1.3	0.2

Each of the four lines of this table has an important significance. First, Chinese imports were largely metal, and have now been reduced to insignificant proportions, the larger proportion of which is crude and oxide. Second, Mexico has practically entirely replaced China, by furnishing a more accessible ore supply for the domestic smelters. Third, South American ores, chiefly from Bolivia, during the first and second periods were of only minor importance, but during the third period have grown to a quite material proportion of the total; it is largely from these ores that the increased output of oxide has been made. And fourth, Mexican and South American ores have practically completely replaced imports from other sources, so that, except for the small amounts still received from China, the domestic antimony supply is centered in the Western hemisphere.

The growing demand for South American ores has resulted from the gradually increasing consumption of antimony oxide, which, as shown by the first tabulation, has more than doubled in con-

sumption during the past decade, and still continues to expand. Curiously enough, this seems at the same time to have been accompanied by a decline in the demand for metal. In 1929, new metal and alloy content made available by imports and smelter output was 46.3 per cent of the total consumption, while secondary metal supplied 37.1 per cent, making a total of 83.4 per cent consumed in metals and alloys, against 12.1 per cent in compounds, chiefly oxide; in 1937 the proportions in new metal and alloys had dropped to 25.6 per cent, while secondary metal had increased to 47.1 per cent, a total of 72.7 per cent, against 25.0 per cent in compounds. The ratio of metal to compounds in 1929 was 6.9, but in 1937 this had dropped to 2.9.

Strategic Aspects—The establishment of domestic smelting has put the strategic position of antimony on a much more favorable basis than formerly existed. The consuming industry is supplied from sources not only far more accessible, but almost entirely in the Western hemisphere, a fact that under present conditions is of prime importance. Were the United States now largely dependent, as it was 10 yrs. ago, on China as the main source of supply, the needs of the present rearmament program would at the best be seriously hampered; and considering the current situation in China and the attitude of Japan, supplies might well be cut off completely. The possibility of interruption of present supplies by outside agencies is much less likely, and transportation difficulties are materially reduced.

The existence of an established smelting industry in the United States also improves the strategic situation in other ways. The stocks of ore and metal normally maintained will be larger; it will be much easier and quicker to expand the capacity of an established smelting plant if and when emergency supplies are required than it would be to build a new one; and likewise, the expansion of an already operating ore supply will be simpler than the development of a new one.

Thus far the operation of domestic smelting has not had any effect on domestic ore production, no smelting of domestic ores having been carried on since the First World War, except for the usual run of hard lead. The new plant at Kellogg, Idaho, will be the first recent attempt to utilize domestic ores for the production of antimony metal, and therefore represents an important step in the program, but one in which possible future development is problematical, except under emergency demand and at prices scaled to fit the conditions involved.

Uses—In 1918 it was estimated that 11 per cent of the domestic antimony consumption went into ammunition. Future war demand for direct munitions work will be much less than this, as shrapnel is no longer used so extensively; but the same change that has outmoded shrapnel (the advent of motorized equipment) has enormously increased the potential demand for antimony in storage batteries for use in the motorized equipment, and at the same time the civilian use of motor vehicles has been expanding rapidly. Where only 4.8 per cent of the antimony consumption went into storage batteries in 1918, this had grown to 28 per cent in 1928; no official consumption distribution figures are available since 1928, but in the meantime motor vehicle registrations have increased by about one-quarter, so that at the present time it is probable that more than one-third of the antimony consumption is going to storage batteries. As a matter of fact, taking into consideration the various other forms in which antimony enters into automobile construction (bearing metals, white alloys, rubber, pigments, etc.), it may be anticipated that the automotive industry now absorbs half or more of the total antimony consumption.

Mention has already been made of the increased use of the oxide, which in 1937 took one-fourth of the consumption, and this, combined with the size and importance of the figures referred to just above, emphasizes the desirability of having a new detailed survey made of the consumption of antimony, so that trends away from the former uses may be estimated more accurately. It is evident that radical changes have been made, but only a systematic and careful survey can give an accurate picture of present conditions and what we may expect in the future, and any estimate of possible future emergency demand is dependent on this information.

Tin

by C. L. MANTELL

Tin is classed as a strategic material in that the United States, the major consumer, produces none, while the major producers consume little. From the advent of tin metallurgy to the present, about three quarters of all the metal has been obtained from ores originating in a relatively small geographic area which includes the Federated Malay States, the Netherlands Indies, Siam, Burma, Indo-China, and lower China. South America (mostly Bolivia) has contributed 12 per cent, all of Europe (including the British Isles) less than 11 per cent, Africa less than 11 per cent, and North America 0.02 per cent. All of the tin won in North America from the birth of the United States would satisfy normal American consumption for less than a week. The United States industry is more completely dependent on faraway sources of supply of tin than is the case with any other material. Insurance against interruption must take the form of adequate stock piles.

The statistical record of tin imports and moved

TABLE I—Salient statistics for tin in the United States, 1925-29 (average) and 1935-39*

	1925-29 (average)	1935	1936	1937	1938	1939
Production—						
From domestic mines ....long tons..	24	44.5	101.0	168.4	95	34 [1]
From secondary sources ....do.....	30,600	24,900	25,000	27,100	21,080	([2])
Imports for consumption (metal) ....do.....	78,009	64,258	76,029	88,115	49,699	70,102
Exports (domestic and foreign) ....do.....	1,740	2,292 [3]	386 [3]	313 [3]	205 [3]	1,997 [3]
Monthly price of Straits tin at New York:						
Highest ....cents per pound..	70.67	52.29	51.85	62.71	46.23	63.50
Lowest ....do.....	39.79	46.91	42.22	42.85	36.84	45.62
Average ....do.....	56.64	50.39	46.42	54.24	42.26	50.20
World production ....long tons..	163,000	135,300	179,000	211,200	159,900	181,000
Ratio United States imports to world production..per cent..	48	47	42	42	31	39

[1] Subject to revision.
[2] Data not available.
[3] Figures for 1935-39 cover foreign only; domestic not separately recorded.
* "Minerals Year Book," U. S. Bureau of Mines.

production in its relation to the United States speaks for itself. (Table I).

Smelting—The United States uses nearly half of the world's production of tin, an amount which is greater than that of all the other leading industrial nations combined. It depends on smelters in Malaya, England, China, and the Netherland E. Indies; formerly supplies also came from a smelter in the Netherlands. Ore originating in Bolivia crosses the Atlantic Ocean to England so that later in the form of tin it may recross the Atlantic to New York.

For practical purposes, large smelters do not yet exist in the United States, although all the technical information, plant experience, and completed development work are available to enable us to treat "foul" Bolivian ores and produce satisfactory metal. During the first World War several successful smelters operated, but the last of them ceased in 1924. Twice in the past tin smelters were established in the United States. Political control in the shape of an export duty on concentrates caused the failure of the first, while commercial control due to more favorable economic conditions abroad put an end to the second.

TABLE II—World smelter production of tin, 1925-29 (average) and 1935-39, by countries, in long tons*

[Compiled by R. B. Miller]

Country	1925-29 (average)	1935	1936	1937	1938	1939
Argentina	.....	591	591	734	1,093	([1])
Australia	2,952	2,837	2,717	2,907	3,229	([1])
Belgian Congo..	.....	1,588	1,955	2,313	2,283	([1])
Belgium [2]	720	4,000	5,100	4,900	6,800	([1])
British Malaya [3].	88,855	60,479	84,591	95,372	63,746	81,536
China	7,080 [4]	9,700	10,400	11,100	11,200	([1])
Germany [5]	3,444	2,042	2,293	2,671	3,000	([1])
Italy	.....	241	286	75	271	([1])
Japan	606	2,036	1,841	1,850	1,900	([1])
Netherland E. India [4]	14,749	11,221	12,854	13,757	7,207	14,788
Netherlands [2] ..	1,000 [6]	15,600	20,900	26,600	25,561	15,024
Norway	([1])	454	233	241	254	([1])
Portugal	2 [7]	1	.....	.....	39	([1])
Thailand (Siam)	113 [8]	([9])	([9])	([9])	.....	([1])
United Kingdom [2] ...	45,800	29,100	34,200	33,800	36,200	([1])
	165,000	139,900	178,000	196,300	162,800	([1])

[1] Data not yet available.
[2] Estimated.
[3] Exports plus difference between carry-over at end and beginning of year.
[4] Exports.
[5] Includes production of some secondary tin.
[6] Estimated production in 1929.
[7] Average for 1926-27.
[8] Average for 1926-28.
[9] Less than 1 ton.
* "Minerals Year Book," U. S. Bureau of Mines.

Sources and Distribution—The world sources of tin are indicated in Table II. The industrial distribution of primary (or imported) tin and secondary (or "circulating") metal is indicated in the Table III, while the sources of the original metal are indicated in Table IV.

Uses.—The major uses of tin are tin plate, solder, bearing metals, bronzes, type metals, collapsible tubes, foil and tin chemicals.

For many of these uses substitutes find employment in times of stress. In the case of foods, other than for esthetic reasons, a considerable number of them may be packed in black plate. In recent years steel electroplated with silver has been suggested for containers, copper-plated steel for oil cans, aluminum (particularly in connection with fish), stainless irons, as well as base metals carrying organic coatings. Enamelware, aluminum, and nickel have largely replaced tin plate in cooking utensils while copper, zinc, and lead-coated products have supplanted tin and terne plate for roofing. Tin foil has suffered from competition of aluminum, cellophane, transparent papers, and lead, while in collapsible tubes aluminum and lead for nonfood purposes have made inroads. Development work on zinc collapsible tubes has been carried to the stage of commercial usage during emergencies.

Effective recovery of the tin from tin plate clippings is made, but the tin content in the average can is lost in the garbage dump. Severe dislocation of natural silk by rayon has markedly affected the consumption of tin chemicals for weighting so that by-product metal, oxides, and plating chemicals are produced instead. Tin oxide as an opacifying agent in glass and vitreous enamels meets effective competition from oxides of antimony, titanium, and zirconium.

TABLE III—Consumption of tin in the United States, 1936-38, by finished products (tin content), in long tons*

	1936			1937			1938		
	Primary	Secondary	Total	Primary	Secondary	Total	Primary	Secondary	Total
Tin plate	33,750	.....	33,750	39,221 [1]	.....	39,221	23,545 [1]	.....	23,545
Terne plate	369	943	1,312	382	1,015	1,397	264	743	1,007
Solder	12,068	6,682	18,750	12,026	7,832	19,858	7,590	5,208	12,798
Babbitt	5,070	1,609	6,679	4,501	2,272	6,773	2,893	1,264	4,157
Bronze	3,559	2,631	6,190	3,712	2,784	6,496	2,334	1,598	3,932
Collapsible tubes	3,556	.....	3,556	3,571	(2)	3,571	3,427	.....	3,427
Tinning	2,377	13	2,390	2,585	67	2,652	1,738	35	1,773
Foil	1,645	43	1,688	1,456	4	1,460	879	(2)	879
Chemicals (other than tin oxide)	209	1,346	1,555	171	1,331	1,502	166	910	1,076
Pipe and tubing [3]	1,401	82	1,483	1,278	18	1,296	948	(2)	948
Tin oxide	969	361	1,330	793	411	1,204	547	444	991
Type metal	253	919	1,172	221	1,140	1,361	134	978	1,112
Galvanizing	1,016	.....	1,016	997	(2)	997	792	.....	792
Bar tin	656	84	740	652	174	826	456	213	669
Miscellaneous alloys	418	62	480	482	24	506	238	19	257
White metal	358	9	367	374	33	407	390	44	434
Miscellaneous	558	34	592	506	97	603	371	107	478
	68,232	14,818	83,050	72,928	17,202	90,130	46,712	11,563	58,275

[1] Includes small quantity of pig tin derived from detinning operations; Bureau of Mines not permitted to publish separate figures.
[2] Small quantity included under "Miscellaneous."
[3] In 1936 pure tin tubing required 1,476 tons and tin-lined tubing 7 tons; in 1937, 1,286 and 10 tons, respectively; not reported separately after 1937.
* "Minerals Year Book," U. S. Bureau of Mines.

Solders—In solders, cadmium alloys have been proposed and found some use, while bearing metals of the babbitt type are being replaced by other alloys or by mechanisms such as ball and roller bearings. Copper-lead, calcium-lead, cadmium-copper-lead, cadmium-silver alloys are all employed as effective and prospective savers of tin. In the bronzes no satisfactory substitute for tin exists, but other alloys of copper, particularly with aluminum, silicon, or manganese, can replace bronze.

Military uses of tin in general are adaptations of the ordinary industrial applications, but in times of conflict between nations the consumption of tin, particularly as tin plate, tin cans, solder, and tin alloys, markedly increases. The status of tin in a preparedness program would be improved by the appearance of commercial smelters in the country, backed by adequate stock piles to cover normal requirements of two or more years. With tin metal normally available, work on substitutes is largely stimulated by some competitive material which seeks a place in the sun. These substances, however, act more as a brake on the tin price than as a mechanism of elimination of tin. In times of stress, however, they may become important aids.

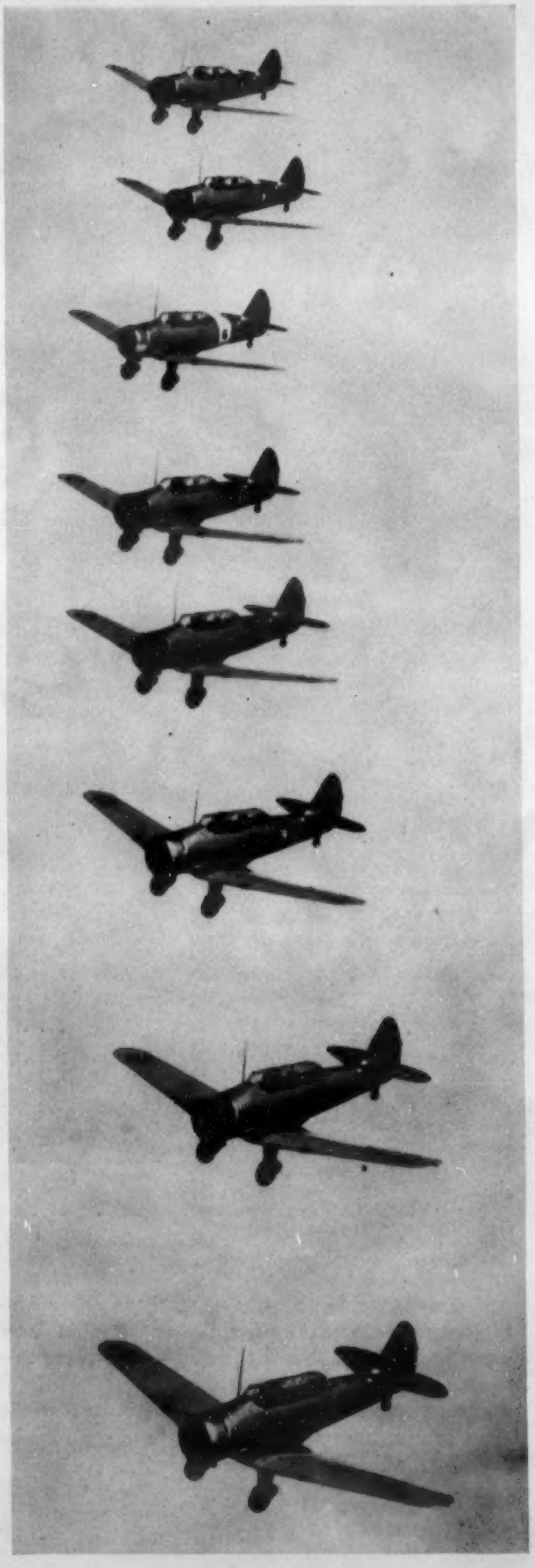
American Smelters—Two American smelters, operating on Bolivian ores are now in operation, a third is contemplated. Output is not large enough to have any appreciable effect in reduction of imports.

In a commercial sense the United States or its possessions has never produced any tin ore, although specimen deposits are known to exist in a large number of locations. The tin content in a pile of old cans in a refuse heap would show a higher tin value than most of our available ore sources. Increases in supply resulting from increased prices of tin would come from secondary sources rather than mining. Until exports were restricted, tin plate scrap in large quantities left the United States. As a conservation measure, the same procedure should be adopted for drosses, slags, and tin-bearing materials so that the tin recovery from these secondary sources may be carried on in the United States to augment our supply.

*TABLE IV**

Country	1938		1939	
	Long tons	Value	Long tons	Value
Argentina	482	$437,762	251	$256,516
Australia	130	126,914	250	256,498
Belgian Congo	75	77,376	100	123,220
Belgium	395	394,518	1,320	1,429,471
Bolivia	25	22,355	....	....
British Malaya	36,673	32,952,813	46,785	47,139,136
Canada	11	8,908	3	2,358
China	2,084	1,807,756	3,259	3,015,954
Cuba	1	481	....	....
Germany	20	17,109	....	....
Hong Kong	1,204	1,034,384	1,062	999,133
Indochina, French	.....	....	25	24,877
Netherland India	3,096	2,716,274	5,316	5,442,528
Netherlands	2,216	2,062,990	1,008	1,018,181
Panama (Canal Zone)	.....	....	(2)	91
Portugal	.....	....	25	27,227
Sweden	(2)	15	....	....
United Kingdom	3,287	3,200,669	10,698	10,855,574
	49,699	44,860,324	70,102	70,590,764

[1] Bar, pigs, blocks, grain, granulated, or scrap, and alloys, chief value tin, n. s. p. f.
[2] Less than 1 ton.
* "Minerals Year Book," U. S. Bureau of Mines.



Mercury

by C. S. WEHRLY

The cycle theorists adapt their formula to many uses. Possibly present phraesology is but a rewording of old beliefs. Atomic change was expressed in terms of a common metal of which mercury was an element. Recent trials proved the inadequacy of present methods to transmute mercury to gold, the value of each is definite.

The low tenor of mercury ore treated in this country is paradoxically of definite benefit. For over 20 yrs. the average metallic content has been but slightly over 0.60 per cent, while for the past 10 yrs. this has declined to under 0.40 per cent. Even with the present duty of over $19.00 per flask, prices in this country are definitely dependent upon prices quoted by Spain and Italy. Thus during periods of low prices our production declines, the converse being equally true. Thus we have a balance or brake upon the hundred odd mines now reporting production which acts to hold our ore in the ground during poor periods and permits fullest operation during peak times. This may be deplored by the producers themselves but reacts to the Nation's benefit.

Output and Prices—Mercury was classified as a strategic metal by the Government and placed upon the export license list. With the jump in prices from slightly over $80.00 in the summer of 1939 to over $200.00 within one year, production, which always lags from six to twelve months, rose from about 1500 flasks per month to 2200 as reported for February, 1940—2500 for March—2700 for April and 3100 for May.

With a present normal consumption need of from 26,000 to 30,000 flasks per annum this country almost from its initial recorded production in 1850 of nearly 8,000 flasks, had up to 1921 been able to export certain quantities. From that year until the present we have been forced to import to make up a deficiency. We are at present freed from the necessity of importation but controlled by conditions outside of this country.

These supplies have come from the three other nations that commercially produce mercury—Spain, Italy and Mexico. While the metal has been found and refined in China, Russia, Germany, Turkey, Africa, Australia, New Zealand, Chile, Peru and other places, it is only these three nations who have produced sufficient quantities to have a marketable surplus. With Mexico's output of from 6,000 to 10,000 flasks, Spain and Italy have supplied the world's needs, normally over 100,000 flasks. Top production has shifted between Spain and Italy but with the recent (1928) agreement, a common selling arrangement eliminated competition between them.

The dominance of these two countries rests in vast reserves and rich ore—Spain over 7 per cent and Italy from $\frac{3}{4}$ to $1\frac{1}{2}$ per cent.

With this power, price fluctuation was under control and limited merely by judgment as to consumer resistance and competitive production. Thus during the years 1928, 1929 and 1930 prices in this country were in excess of $115.00 per flask and production rose from 11,000 flasks in 1927 to over 21,000 flasks for that period. Estimated reserves in the United States excluding ore testing lower than 0.1 per cent (a possible development) are placed at over 150,000 flasks. With widespread occurrence, possible undiscovered ore bodies and economic barriers upon production, this country does not need to fear a shortage in times of stress.

Uses and Substitutes—The value of mercury rests in the lack of substitutes and its widespread application. Its uses are so varied that each of us daily is affected by its presence. Generally the fields are divided into chemical, electrical and mechanical uses and adaptations. The first is today the largest; using over 60 per cent of the total. Included are the well-known salts, organic compounds, vermilion, acetic acid and dyestuffs. While the rate is small, normally these uses are decreasing. Fulminate no longer is the only detonator.

Electrical uses call for about 8 per cent but the most important—diffusion lamps and cells for the production of caustic soda and chlorine—are experiencing wider application. Battery zincs, arc rectifiers and miscellaneous uses are included in this group. The mechanical field which embraces meters, barometers, hydrometers, thermometers, gages, thermostats and pressure control devices accounts for about 13 per cent of the total.

In addition to these three general classifications the preparation of hatters felt—consuming over 10 per cent of the total—gold amalgamation, dental amalgams, alloys and laboratory uses make up the total from which, however, has been excluded the mercury boiler whose installation and, hence, use of mercury is not assessable to any one year. In this boiler present usage calls for about 7 lbs. per k.w. which multiplied by 40,000 or 50,000 is a ponderable item.

As a whole, the consuming industries are fairly constant in the quantity used, those whose use is declining being offset by others whose demand is increasing. Mercury's value in war-time is no longer its use as a detonator, which use, however, can increase a thousandfold over peace-time requirements, but in its definite irreplaceable position in industries which affect safety, health and the daily life of all persons. We shall probably experience new uses, discard others but its value has existed for centuries. Its future may be altered in aspect but not in demand.

Beryllium and National Defense

Much publicity in the daily press and on the radio has been broadcast recently as to the role of beryllium and its alloys in our rearmament program.

In view of the importance of this subject, we asked the author of this brief article to state his views frankly and fully as to its strategic value. He is one of the best posted men on this subject in the country. —The Editors.

by C. B. Sawyer

Brush Beryllium Co., Cleveland

RECENTLY THERE HAVE BEEN SEVERAL broadcasts, newspaper articles and stock brokers' statements to the effect that beryllium has a revolutionary and vital part to play in national defense, and Representative Brewster of Maine, whose state contains some beryl deposits, has introduced a bill (HR 10185) to have beryllium declared a strategic war material. There are rumors also, of requests for a sum of $500,000 to be made available from the U. S. Treasury for the development of the beryllium industry.

The author of the present article who has been actively engaged on research and commercialization of beryllium since 1921, disagrees with the inferences which one is led to draw from this publicity and

is opposed to the measures suggested. It may be well to consider what other materials are available to accomplish the purposes indicated for beryllium.

Beryllium-Nickel—At the hearing on the beryllium industry before the Temporary National Economic Committee in May of 1939, a great deal of stress was laid on the very vital part which beryllium-nickel would play in the airplane industry and diagrams of tensile strength were submitted. No mention was made, however, of competing heat-treated materials already available on the market. The writer submitted supplementary testimony after the hearing which was made a part of the record early in 1940, showing how heat-treated steels compared favorably in tensile strength with heat-treated beryllium-nickel. It may be stated that none of several government officials, since consulted, has expressed the point of view that beryllium-nickel, either heat treated or not, has a revolutionary or vital part to play as a structural material in airplanes. Certainly enough time has elapsed since the hearing to have produced the necessary evidence of such a revolutionary or vital part if it does now exist.

Beryllium-Copper—Much has been said also about beryllium-copper for low-sparking tools to overcome the hazards of plants dealing with explosives. Lead tools, bronze tools or nickel tools have been used for this purpose heretofore, though beryllium copper tools have an advantage where a good cutting edge is required.

Similarly in the case of beryllium-copper castings of such close tolerance that little additional finishing is necessary, it has been represented that this provides a key to the opening of the bottle-neck of national defense which exists due to the many necessary machining operations.

An illustration is made of a cast part of beryllium copper for the Garand rifle which is said to have astonished army engineers by slipping directly into place without the necessity of additional machining. So far as can be ascertained, about a dozen castings from a single pattern were produced in plaster molds by a process developed by a well-known company and tests on these parts, favorable or otherwise, have not yet reached the production stage. Here again, though beryllium-copper does have good flowing qualities when cast, the process developed above was primarily for other copper-base alloys already in common use and it is doubtful if, in the application suggested above, further finishing operations can be omitted.

Allusion has been made in recent publicity to some intensive work being carried out by one of the large airplane companies on a revolutionary method employing beryllium-copper. Here again it is understood that certain aluminum base alloys may also be used for the purpose concerned. Even though the physical properties of high conductivity beryllium-copper may be preferable, the project would not necessarily fail if its present highly experimental stage cannot be brought to a successful conclusion using beryllium-copper.

German Patents—Much has been said also on the subject of control of the industry by German patents. It may therefore be appropriate to remark that the company with which the author is associated has developed its own processing patents in the United States and owns them, as well as certain patented beryllium-copper alloys with nickel additions (U. S. Patent No. 2,167,684) and has in successful operation a commercial production plant of sizeable capacity. In the opinion of an eminent firm of lawyers, these alloys are entirely free from domination by any patents of German origin, or of American origin for that matter, not only as to composition but also as to heat treatment. A large insurance company is willing to back this opinion with insurance against damages.

For those who are fearful of the "supremacy of German research," attention is directed to the fact that the present relatively inexpensive arc furnace process for the direct production of beryllium-copper from carbon, beryllium oxide and copper was first put into commercial operation by the author and his associates. This simple arc process, in conjunction with their other processes, has permitted them to assume and maintain that leadership in price reduction of 4 per cent beryllium-copper master alloy disclosed at the T.N.E.C. hearing.

Though the basic idea of this process was disclosed by Lebeau in 1897, so many obstacles existed to its commercial operation that various attempts by the Germans (see U. S. Patents Nos. 2,025,614 and 2,025,616) were unfruitful. Success was not achieved with this process until the work in the United States by the author and his associates. This is expressed in their U. S. Patent No. 2,176,906 which has claims covering several improvement steps, one or more of which is believed to be necessary. No license to use this patent has been granted. Inventors in the United States are quite able to take care of themselves.

Ductile Beryllium—If a revolution can be effected in industry through the use of beryllium, it would probably come by making this "light" brittle material ductile. The same may be said of the element silicon which is almost as "light" as beryllium or magnesium and vastly more abundant than either, though too brittle for direct use. The commercial production of ductile beryllium seems still far removed from the present, and there is, therefore, no purpose in stressing its light weight. The author collected and reported the results of his research and those of others on the physical properties of beryllium in METALS AND ALLOYS for June of the current year.

Commercial Outlets—The present commercial outlets for metallic beryllium are principally as a hardener for base metals when beryllium is added in small amounts. Of these, beryllium-copper is by far the most important. The American Brass and the Riverside Metal companies deserve much credit for their mill and sales development work in the production of rod, sheet, tube, wire and other fabricated forms of this metal and have incurred the usual discouragements and expense inherent in such pioneer work. In the castings field The Ampco Metal Company has filled a similar rôle. Beryllium-copper is characterized by high strength, hardness, high endurance limit, high resistance to fatigue and resistance to corrosion.

This beryllium alloy, when properly produced, is about 50 per cent stronger than its next nearest copper base competitor, and could therefore compete directly at a price per pound about 50 per cent greater than this competitor. No such price competition with cheaper alloys now exists and beryllium copper alloys must, therefore, at present be content with those limited commercial fields open to them by virtue of special combinations of requirements only partially met by other alloys. The same is true of other base metal alloys such as beryllium-nickel, where beryllium enters only in small amounts.

Ore Supplies—The supply of ore for the beryllium industry has always exceeded the demand and has grown faster, if anything, than the industry which it nourishes. Nevertheless the ore supply is not unlimited and were any very great demand to appear, the supply might prove temporarily inadequate.

It seems a pity that the development of the beryllium industry should be associated with so much flag waving and untimely publicity. The industry will probably follow the course of other similar industries which is one of development over a very considerable period of time. Results are not achieved over night and this is a fact which should be brought to the attention of ore prospectors, potential investors, legislators and others who may be affected.

Dr. Zay Jeffries' review of beryllium in the January, 1940, issue of *Mining and Metallurgy,* p. 10, of the American Institute of Mining and Metallurgical Engineers, states, with reference to the T.N.E.C. hearing that: "Newspapers, columnists, and the radio carried messages to the public which sounded spectacular and were, in fact, fantastic. Now that the investigation is over and the publicity has subsided, it can be reported that the beryllium industry is still going forward in the only manner in which a new metal industry can grow, namely, through technological development, including cost reduction, the improvement of beryllium products, and the dissemination of sound information concerning commercial applications."

Feature Articles on Preparedness and Defense

In the following section of this issue there will be found several articles which are related, directly or indirectly, to the American Preparedness and Defense Program.

There are two discussions of certain essential airplane materials—magnesium alloys and a new method of making aircraft stampings.

Discussions relating to armor plate and the electric furnace, the strategic relation of tin to bearings, and tinplate and solder; the problem of flakes and cooling cracks in forgings; electric detection of flaws in tubing for airplanes and other uses are also included. Other articles of this nature will appear in later issues.

Many metallurgical engineering subjects involved in defense could not, for obvious reasons be treated, though attempts were made to secure these.

Magnesium in Aircraft

by NORMAN E. WOLDMAN

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While aluminum is, and has been for some time, the principal metal involved in airplane production, the importance of magnesium and its alloys is expanding in this field. The lower the dead weight of a plane, the more passengers and freight it can carry. Similarly, the lighter the plane, the more armament it can carry. The alloys of magnesium are lighter than those of aluminum.

Realizing that magnesium is more and more a factor in airplane construction, we asked Dr. Woldman to contribute this illuminating discussion. It bears directly on the present armament for defense program of our Government.—The Editors.

THE CONSTANT DEMAND through the development of the aircraft industries has been for stronger and lighter alloys. This became more apparent as the airplanes were being built larger and heavier. The efficiency of an airplane, at least from a commercial viewpoint, is measured by its pay load or the useful weight which it can lift and transport. The lower the dead weight of a plane of a given design, the more passengers and freight it can carry. The efficiency and ease in maneuvering of military planes are affected by the total weight. For the same horsepower rating, the lighter the plane the greater the maneuverability. And with similar thought, the lighter the plane the more armament it can carry.

Aluminum and its alloys were introduced extensively during the early stages of the aircraft industry. Due to their low density, high mechanical strength and great durability, great savings in weight were obtained. The fuselage, the wings, the tail, the rudder, the propellor and many of the engine parts were made from wrought, cast and forged aluminum alloys. Later, there were introduced, first in Europe then in the United States, the alloys of magnesium under the trade names of Electron, Magnuminium, Dowmetal and Mazlo (A.M. Alloy). These alloys were lighter than aluminum and just as strong in the cast condition. Today, magnesium has found its place in the aircraft industry and its applications are constantly on the increase.

Properties of Magnesium Base Alloys

Magnesium base alloys have characteristics which place them in a separate class from other base alloys. They are the lightest structural alloys yet known, being two-thirds the weight of aluminum and one-fourth the weight of iron and steel. Many of the alloys respond to heat treatment which gives them greater physical strength. They also possess excellent machinability, toughness and fatigue endurance. They have a high strength-weight ratio, which means that on an equal weight basis their strength is equal or superior to that of most other metals. The relative densities of magnesium and other aircraft metals and alloys are shown in Table I.

A true appreciation of the characteristics of magnesium alloys and their suitability for aircraft structures, requiring maximum strength and endurance with a minimum weight, is obtained when their properties are compared with those of other commercial metals. Gann[4] showed in the tables below (Tables II and III) that heat-treated magnesium alloy castings are equal to the high strength aluminum alloy castings, volume for volume, and are superior to the high strength aluminum alloys when equal weights are compared.

For Table III the cross-section area of the aluminum and magnesium alloy parts had been increased until they weighed the same as the steel section. Thus it is seen that the properties that fit the magnesium alloys for aircraft use are their extreme lightness, high strength and good fatigue endurance, that is, their ability to withstand repeated applications of stress.

Various Products

Magnesium alloys can be produced in the following forms:

(1) Castings: Sand cast, permanent mold and die cast.
(2) Forgings: Hammer and press forgings.
(3) Wrought: Extrusions, sheets, plates and bars.

Table I. Relative Densities

	Specific Gravity	Lbs. per cu. in.
Magnesium	1.8	0.065
Aluminum	2.7	0.101
Zinc	7.1	0.256
Cast Iron	7.2	0.260
Steel	7.9	0.285
Stainless Steel	7.92	0.286
Brass	8.5	0.307
Bronze	8.8	0.318
Monel	8.9	0.323
Copper	8.9	0.323

Castings

Sand castings are used most extensively and comprise the largest consumption of magnesium alloys. Where production and design warrants, permanent mold or semi-permanent mold castings are used. For small parts where little machining is necessary and smooth surfaces are required, die castings are used. Forgings have been introduced for highly stressed parts. And now, through new developments in manufacture, we have available sheets, bars, extrusions, etc., to be fabricated by riveting or electric spot welding into such fuselage assemblies as doors, hatches, floors, seats, instrument assembly panels, partitions, air ducts, etc.

Heat Treatment: As is true with the aluminum alloys, only a part of the total number of available magnesium alloys are susceptible to heat treatment. This heat treatment, which is a solution treatment with or without an aging treatment, produces the optimum physical properties. The solution treatment consists in heating the parts to 650 to 720 deg. F. for a sufficiently long time (16-20 hrs.) until the insoluble constituents go into solid solution, then air cooling. This treatment increases the strength and ductility to maximum toughness. However, when this treatment is followed by an aging treatment at 340 to 400 deg. F. for 12 to 16 hrs., the tensile strength and hardness increase still further with a sacrifice in ductility. The former treatment is designated in the field as "H.T." or "S.T." while the latter treatment is designated as "H.T.A." or "S.T.A."

Table II. Comparative Properties of Dowmetal vs. Other Metals—Equal Volume Relations

Name	Relative Weight	Tensile Strength	Elongation, Per Cent	Fatigue Endurance Limit in Bending
Mild Steel	4.4	60,000	30	30,000
Alloy Steel	4.4	100,000	20	50,000
Aluminum Alloy, Cast, Heat Treated	1.6	33,000	8	.....
Duralumin	1.6	60,000	20	15,000
Dowmetal, Cast, Heat Treated	1.0	33,000	10	9,000
Dowmetal, Wrought, Heat Treated	1.0	42,000	12	14,000

Table III. Comparative Properties of Dowmetal vs. Other Metals—Equal Weight Relations

Name	Relative Weight	Tensile Strength	Fatigue Endurance Limit in Bending
Mild Steel	4.4	60,000	30,000
Alloy Steel	4.4	100,000	50,000
Aluminum Alloy, Cast, Heat Treated	4.4	91,000	.....
Duralumin	4.4	172,000	70,000
Dowmetal, Cast, Heat Treated	4.4	145,000	80,000
Dowmetal, Wrought, Heat Treated	4.4	185,000	125,000

Fig. 1. Sand casting for the nose piece for the Pratt & Whitney radial engine.

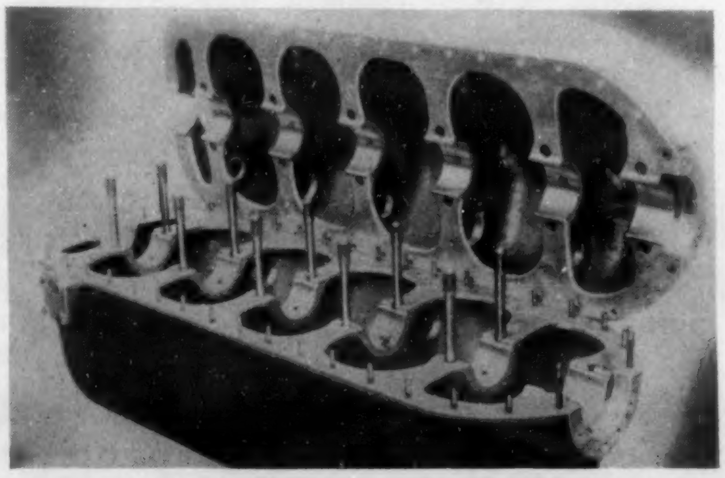
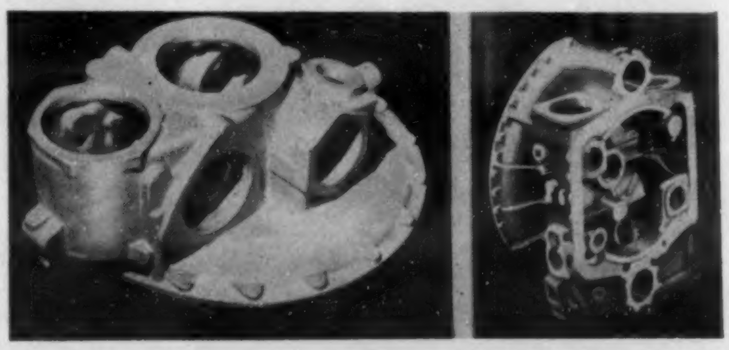


Fig. 2. Sand casting for crankcase and top cover for the De Havilland "Gipsy Minor" engine.



Figs. 3 and 4. Die cast rear crankcase rear cover for the Bristol engine (left), and sand casting for the front supercharger casing for the Napier "Dagger" engine.

Characteristic Uses of Castings

Magnesium casting alloys may be classified according to their characteristic uses, as follows:

(1) *For moderate tensile strength and leak proofness:*
Dowmetal G and AM-240
Sand castings and permanent mold castings
Composition: 10.0 Al, 0.10 Mn, bal. Mg
Respond to heat treatment

(2) *For high impact strength and high ductility:*
AM-241
Sand castings and permanent mold castings
Composition: 8.0 Al, 0.1 Mn, bal. Mg
Respond to heat treatment

(3) *For high hardness, high yield strength, but low elongation:*
Dowmetal B and AM-246
Sand castings
Composition: 12.0 Al, 0.1 Mn, bal. Mg
Respond to heat treatment

(4) *For soundness, and leak-proofness and requiring high strength:*
Dowmetal C and AM-260
Sand castings
Composition: 9.0 Al, 0.1 Mn, bal. Mg
Respond to heat treatment

(5) *For high physical properties and fine grain:*
Dowmetal H and AM-265
Sand and permanent mold castings
Composition: 6.0 Al, 0.2 Mn, 3.0 Zn, bal. Mg
Respond to heat treatment

(6) *For good stability and welding characteristics:*
Dowmetal M and AM-403
Sand castings
Composition: 1.2-2.0 Mn, 0.3 max. Si, bal. Mg
Do not respond to heat treatment

(7) *For thin wall die castings of moderate strength:*
Dowmetal K and AM-230
Die castings
Composition: 10.0 Al, 0.10 Mn, 0.5 Zn, bal. Mg
Do not respond to heat treatment

(8) *For good strength die castings (general):*
Dowmetal R and AM-263
Die castings
Composition: 9.0 Al, 0.2 Mn, 0.6 Zn, bal. Mg
Do not respond to heat treatment

The *typical* physical properties for the above alloys are shown in Table IV.

Dowmetal H (AM-265) is the chief sand cast magnesium alloy used today. It has replaced to a great extent Dowmetal G (AM-240) due to its superior corrosion resistance and also due to its higher tensile strength and its higher ductility after heat treatment.

Forging Alloys

Magnesium forging alloys are divided into press and hammer forgings. But since higher strength forgings are obtained when they are press forged, hammer forgings are scarcely used. These forging alloys may also be classified according to their characteristic uses as follows:

(1) *General forging, good ductility:*
Dowmetal G and AM-57S

(2) *Strong forgings, simple design:*
Dowmetal O and AM-58S

(3) *Heat-treatable forgings:*
Dowmetal X and AM-74S

(4) *Weldable forgings:*
Dowmetal M and AM-3S

The chemical composition and physical properties of these alloys are given in Table V.

Wrought Alloys

Magnesium alloys have been developed which can be mechanically worked, rolled, extruded and drawn, thereby causing marked improvement in physical properties. Rolled sheet can be made in thickness down to 0.005 in. Rolled plate, sheet and strip alloys are classified as follows:

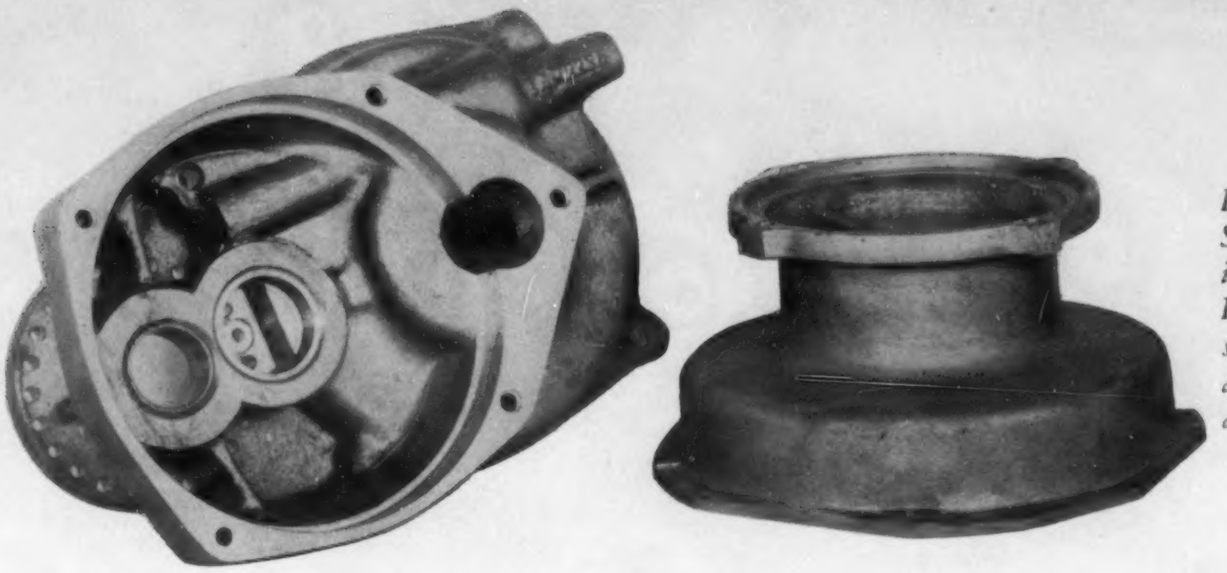
(1) *High strength:*
Dowmetal E
Dowmetal F and AM-53S

(2) *Best formability and salt water resistance:*
Dowmetal M and AM-3S

The chemical composition of these alloys are as follows:

	Dowmetal E	Dowmetal F AM-53S	Dowmetal M AM-3S
	Per Cent	Per Cent	Per Cent
Aluminum	6.5	4.0	——
Manganese	0.2	0.3	1.5
Magnesium	bal.	bal.	bal.

Fig. 5. Sand cast starter housing, finish machined, chrome pickled and painted.



Figs. 9 and 10. Sand cast front housing (left) for Eclipse Starter; note steel bearing liners; and sand casting for a starter motor bracket.

These alloys are supplied in the annealed and hard rolled condition. *The typical* physical properties of these alloys are as follows:

	Dowmetal E Annealed	Dowmetal E Rolled	Dowmetal F AN-53S Annealed	Dowmetal F AN-53S Rolled
Tensile strength	34000	45000	36000	44000
Yield strength	20000	34000	22000	35000
Elongation (per cent) ..	15	9	18	10
Brinell	57	70	50	60

Table IV. Typical Physical Properties of Mg Alloys

	AM-240 Dowmetal G H.T.	AM-240 Dowmetal G H.T.A.	AM-241 H.T.	AM-246 Dowmetal B H.T.A.	AM-260 Dowmetal C H.T.	AM-260 Dowmetal C H.T.A.
Tensile strength..	33000	34000	33000	32000	38000	38000
Yield strength....	12000	19000	11000	20000	14000	20000
Elongation, per cent	8	1.0	10.0	0.5	10	3.0
Shear strength....	20000	22000	18000	19000	20000	22000
Charpy impact....	.....	0.7	2.2	0.5	.....	0.8
Brinell	52	69	48	85	61	78
Endurance limit..	10000	8000	7500	7000	10000	10000

	AM-265 Dowmetal H H.T.	AM-265 Dowmetal H H.T.A.	AM-230 Dowmetal K as cast	AM-263 Dowmetal R as cast	AM-403 Dowmetal M as cast
Tensile strength	37000	37000	30000	33000	14000
Yield strength..	12000	18000	22000	20000	4000
Elongation, per cent	10.0	4.0	1.0	3.0	5.0
Shear strength..	18000	19000	.....	.....	11000
Charpy impact..	2.5	1.1	.....	.....	.....
Brinell	53	69	68	66	33
Endurance limit.	10000	9000	.....	.....	.....

Table V. Chemical and Physical Properties of Forging Alloys

	AM-57S Dowmetal J Per Cent	AM-58S Dowmetal O Per Cent	AM-74S Dowmetal X Per Cent	AM-3S Dowmetal M Per Cent
Aluminum	6.5	8.5	3.0	..
Manganese	0.2	0.2	0.2	1.5
Zinc	0.7	0.5	3.0	..
Magnesium	bal.	bal.	bal.	bal.

	AM-57S Dowmetal J	AM-58S Dowmetal O	AM-74S Dowmetal X Forged	AM-74S Dowmetal X Aged	AM-3S Dowmetal M
Tensile strength...	41,000	45,000	41,000	42,000	33,000
Yield strength....	25,000	30,000	24,000	28,000	19,000
Elongation, per cent	9	7	16	14	6
Brinell	56	69	59	62	43
Shear strength....	21,000	22,000	.....	.....	.....
Endurance limit..	15,000	16,000	17,000	17,000	.....

The forming of magnesium alloy sheets and shapes can best be done at a temperature of 500 to 700 deg. F., due to a tendency of the material to harden rather rapidly with cold working. A limited amount of cold working is possible but liberal bend radii should be allowed.

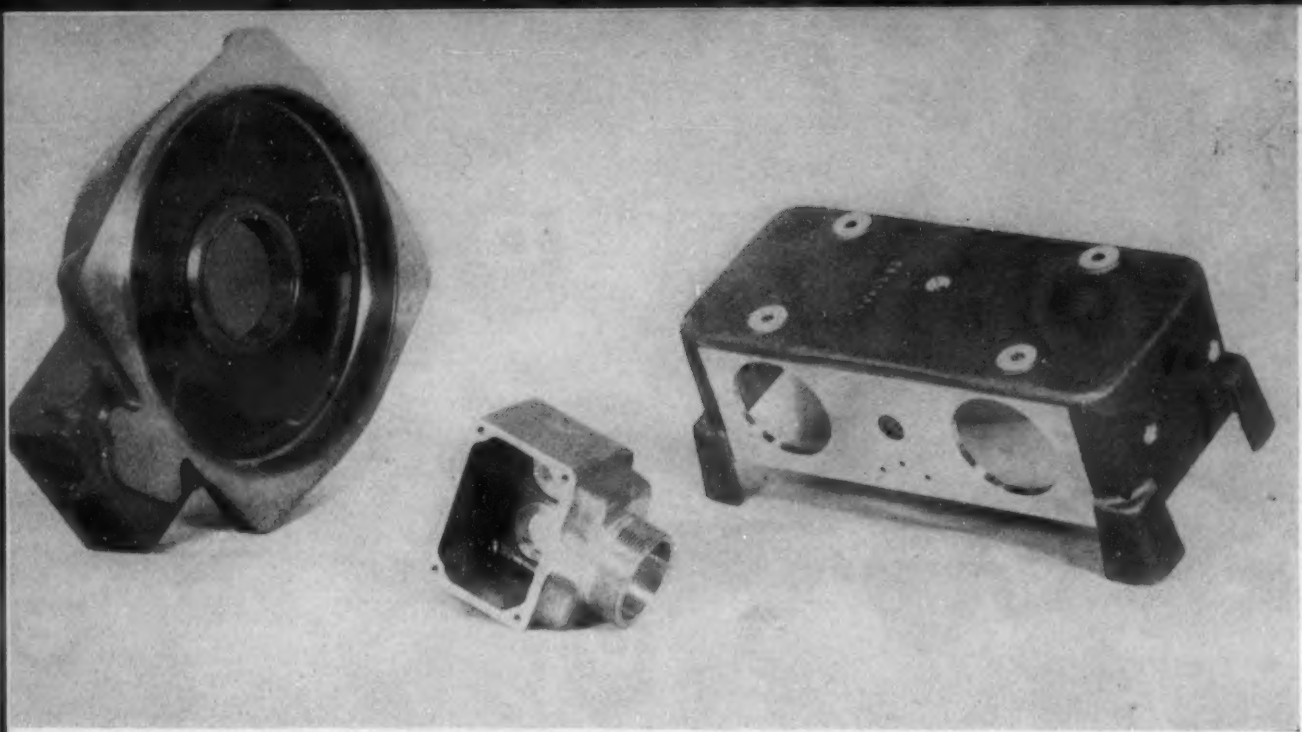
For chemical composition and physical properties of the various magnesium alloys used for extruded structure shapes, bars, rods and tubing, the reader is referred to the publications of the Dow Chemical Co. and the American Magnesium Corp., Division of the Aluminum Co. of America.

Some General Properties

Magnesium alloys, while possessing good tensile properties and good resistance to fatigue, are very sensitive to local concentration of stresses, that is, they are notch sensitive. For this reason notches and scratches of all kinds must be avoided. Sharp corners should be eliminated wherever possible. Highly stressed castings should be provided with liberal fillets.

The designer of magnesium alloy parts should

Figs. 6, 7 and 8. Sand cast main housing (left) for Eclipse Alternator, finish machined, chrome-pickled and painted; finished sand cast intermediate housing (center) for Eclipse Flap Motor, and finished sand cast front housing for Eclipse Series 41 Starter.



Figs. 11, 12 and 13. Sand cast back head (left) for Eclipse Starter; sand cast terminal housing (center) for Eclipse Starter, and sand cast electric control box.

avoid cavities and pockets where moisture can accumulate and cause corrosive attack. Such cavities or pockets, however, can be coated with a lacquer such as Glyptal. Electrolytic action of magnesium in contact with other metals must be avoided. Brass and steel parts in contact with magnesium are usually tin or cadmium plated, preferably cadmium.

Magnesium alloys can be used safely at low temperatures, such as are encountered by aircraft at high altitudes, but are not recommended for high temperatures, such as above 400 deg. F. It has been found that at —120 deg. F. the yield strength is about 10 per cent greater and the elongation is about 20 per cent less than at room temperature.

Magnesium alloys ordinarily are not recommended under conditions requiring resistance to wear. However, they may be used where ample lubrication is provided. Steel shafts may be run directly in magnesium castings where sufficient lubrication is provided and where the bearing load and speeds are not excessive. Where this is not feasible, iron or steel inserts can be used as liners in the castings. These liners can be shrunk, pressed or cast in.

The modulus of elasticity of magnesium is very low, namely, 6,500,000 lbs. per sq. in. This is two-thirds the modulus of aluminum and about one-fifth the modulus for steel. Therefore, when changing the structural part from steel or aluminum to magnesium, it is usually found necessary to stiffen up the section. Ribbing or corrugating the walls, increasing wall thicknesses or deepening sections are effective methods of producing the desired stiffness with the least weight of metal. Further, since magnesium alloys are apt to distort more readily than other alloys under load, it is advisable to support the surrounding metal at the edge of bolt holes and other places subject to stress concentration by thickening the section.

Corrosion and Its Prevention

Years ago the objection to magnesium alloys was its lack of stability in salt water, and even to some extent in fresh water. Magnesium alloys corroded very rapidly, developing pits and a grayish-white incrustation. The current magnesium alloys are reasonably stable under most atmospheric conditions, which has been attained by careful purification and the addition of manganese. However, in salt atmospheres they are somewhat subject to pitting and roughening. Nevertheless, where corrosion does occur in long time exposure tests, the slight loss in strength is equivalent to the loss in area, but there is no loss in ductility or strength that can be attributed to intercrystalline corrosion.

Castings and wrought parts are usually given an anticorrosive treatment known commercially as a chrome pickle. This is nothing more than a quick dip (20 to 60 secs.) in a solution of sodium dichromate, concentrated nitric acid and water. This produces an iridescent, yellow, porous coating of sparingly soluble chromic chromates on the surface, which is intimately bonded to the metal. It also provides a good base for subsequent painting and has definite anticorrosive properties. Where service conditions are particularly severe, the metal should be protected with a lacquer, paint or enamel. The best protection is obtained by first chrome pickling, then covering with a layer of zinc chromate primer, and finally with one or two coats of a good paint, varnish or lacquer.

There are several methods recommended for chemically treating magnesium alloy parts for increased resistance to corrosion. These may be briefly described as follows:

(1) *Chrome Pickle Treatment:* 20 to 60-second dip in a sodium dichromate-nitric acid solution at room temperature. It produces a matte iridescence with yellow and red shades predominating. Dimensional loss is from zero to 0.0005 in., depending on the time of immersion. Parts containing brass or steel inserts can be so treated. Known as Dow Treatment No. 1 and American Magnesium Co. treatment No. A.

(2) *Dichromate Treatment:* Five minute immersion in 15 to 20 per cent HF, followed by a 45-min. immersion in 10 per cent sodium dichromate solution. It produces a dark brown to black coating. Dimensional changes are practically nil. Brass, bronze or steel in-

serts are unaffected. Known as Dow Treatment No. 7 and American Magnesium Co. treatment No. G.

(3) *Modified Alkali Chromate Treatment:* Five minute immersion in 15 per cent HF, followed by a 45-min. immersion in a solution of ammonium sulphate, ammonium dichromate, sodium dichromate and ammonia, then finally immersed in a 1 per cent arsenous oxide solution. This produces a black coating. This treatment produces no dimensional loss, but may gain up to 0.0003 in. Brass, bronze or steel inserts are unaffected. Known as Dow Treatment No. 8 and American Magnesium Co. treatment No. H.

(4) *Galvanic Anodize Treatment:* Immerse for 5 min. in a 15 to 20 per cent HF solution, then immerse and galvanically anodize the parts for 30 min. in an ammonium sulphate, ammonium dichromate and ammonia solution at room temperature. This will produce a dark gray to black coating. No dimensional changes are produced. Brass, bronze or steel inserts are unaffected. Known as Dow Treatment No. 9 and American Magnesium Co. treatment No. K.

(5) *Sealed Chrome Pickle Treatment:* Same as standard chrome pickle except that it is followed by a second immersion for 30 min. in a boiling solution of 10 to 20 per cent potassium dichromate to seal the pores for increased resistance to corrosion. Brass, bronze or steel parts are unaffected. Dimensional loss is from zero to 0.0005 in. Known as Dow Treatment No. 10 and American Magnesium Co. treatment No. L.

Magnesium alloy parts for aircraft electrical systems and other parts requiring coatings possessing low electrical resistance for bonding purposes are given either the standard Chrome Pickle treatment or the Sealed Chrome Pickle treatment, preferably the latter. All the other treatments produce a higher dielectric film on the surfaces, which are more corrosion resistant than the Chrome Pickle treatments. Engine parts are given the more desirable Galvanic Anodize treatment or the Dichromate Chemical treatment.

Magnesium alloys in present commercial, sport and military airplanes comprise less than 1.5 per cent of the total weight of the plane. However, with the new developments in fabricating magnesium alloy wrought parts and with the recent improved developments in anticorrosive chemical treatments of magnesium alloys, the aircraft industry is expected to increase the per cent of magnesium in the total weight of the plane. The European aircraft manufacturers have adopted magnesium alloys more readily than the American manufacturers.

Applications in Aircraft

The present application of magnesium alloys in aircraft may be listed as follows:

Sheets, bars, extrusions:

Doors, hatches, floors, seats, instrument assembly panels, partitions, air ducts, furniture and secondary structures. Sheets are used extensively abroad in the construction of fuel tanks, oil tanks, cowling and fairing. The main spars of the 12-engined flying boat, The DO-X, were made of extruded magnesium alloy.

Forgings:

Propellor blades, supercharger impellers, engine pistons, engine crankcases, engine nose sections, supercharger rollers.

Castings:

Permanent Mold Castings

Landing wheels

Die Castings

Engine rocker box covers, shroud tube fittings

Sand Castings

Engine crankcases, gear cases and covers, engine nose sections, tail wheel assembly parts, brake assemblies, starter housings, pump housings, intake manifolds, oil sumps, supercharger rollers, hydraulic pump bodies, thrust bearing housings, diffuser plates, camshaft housings, generator housings, window frames, pedals, wheels, tail forks, deicer pumps, blower sections, engine rear sections, automatic pilots, distributors, instrument cases and parts, control column parts, rear and front supercharger sections.

The illustrations represent some of the aircraft engine or accessory parts made of magnesium alloys.

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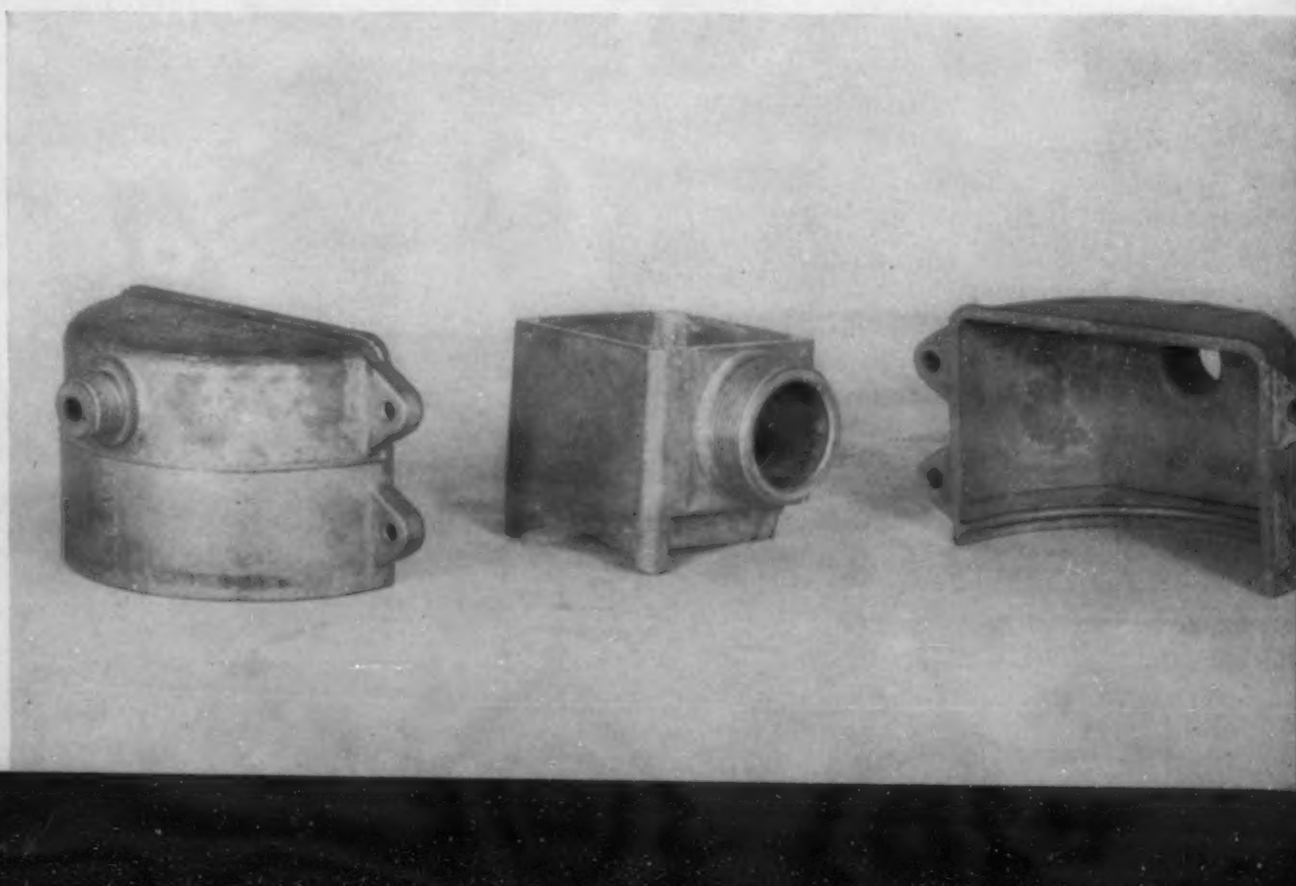


Figs. 14, 15 and 16. Die casting for Eclipse Starter (left) motor shield; die casting for starter housing terminal (center), and die casting for starter motor shield.

Producing Aircraft Stampings

by HERBERT CHASE

Stampings of many kinds and of many materials are used extensively in manufacturing modern airplanes, military or transport.

In this article, another relating to preparedness in aircraft, the author describes the latest methods used by the Douglas organization in producing certain stampings, largely from aluminum and magnesium alloy sheets.

Involved in these is the use of a special zinc or moderately soft alloy instead of steel or cast iron for the dies. The Guerin process is also discussed. In this a punch of rubber is used instead of a metal one, with surprisingly interesting and effective results.—The Editors.

Section of the Douglas plant showing, at the left, some of the many dies, most of them cast from zinc alloys, which are used on rope drop hammers (some of which are seen at right) to produce deep drawn stampings.

In recent years, plants for the production of airplanes have ceased to be primarily wood working plants and have become, instead, plants chiefly engaged in doing sheet metal work. As their production capacity has been increased, they have, as far as conditions permit, adopted methods similar to those used by other large fabricators of sheet metal, but have often been prevented from making use of "high" production methods because the quantities of most parts required have not justified the investment in tooling which is necessary and highly economical when the number of duplicate parts required is much greater. Instead, some of these plants have developed substitute methods which, though seldom as economical as those used where quantities are much larger, are still a great advance over the hand methods necessarily employed during the early part of the transition period from wood to metal fabrication.

Few have done as much in the development of more economical production of sheet metal parts as Douglas Aircraft Co., Inc., Santa Monica, Calif. Many entirely new methods have been devised and the plant is now following some production practices in manufacturing sheet metal parts which might well be studied by those plants where relatively short runs are the rule.

Specialized Dies

Except for certain small parts which are required in considerable numbers per plane and which justify the use of conventional forms of presses and the employment of steel or cast iron dies, a large proportion of sheet metal parts are made in somewhat specialized dies which, though not having the life or the production capacity of steel or cast iron dies, cost much less and are a great advance over the use of hand tools.

Such dies are amply justified on an economic basis and have adequate life for the total run required of them. They turn out stampings of high quality and at a rate which is often much more rapid than that at which the parts can be built up into assembled structures. Some of the dies involve non-metallic parts, but the critical parts and those subjected to wear or to extreme pressures are usually of metal, often alloys which are softer than the sheet stock to be worked in them. This stock is most commonly Duralumin or some other aluminum alloy, but includes also magnesium alloys and certain steels, chiefly of the stainless varieties, all having high strength-weight ratios.

Such stampings as are required in quantities sufficient to justify the use of steel or cast iron dies need not be dealt with here, as the equipment does not depart greatly from that used conventionally elsewhere for similar parts in like quantities. It is chiefly the short run type of product that need be considered here, as its production involves the innovations which are of chief interest. Often, not more than a few hundred of the parts in question are needed, but they must be held within close tolerances and must be produced in some form of die so as to meet engineering requirements and also come within desired cost limits. Some of the parts are quite large and necessitate quite deep drawing which would require exceedingly expensive drawing and blanking dies if the quantities were large enough

in the Douglas Plant

and the types of dies here described were not available.

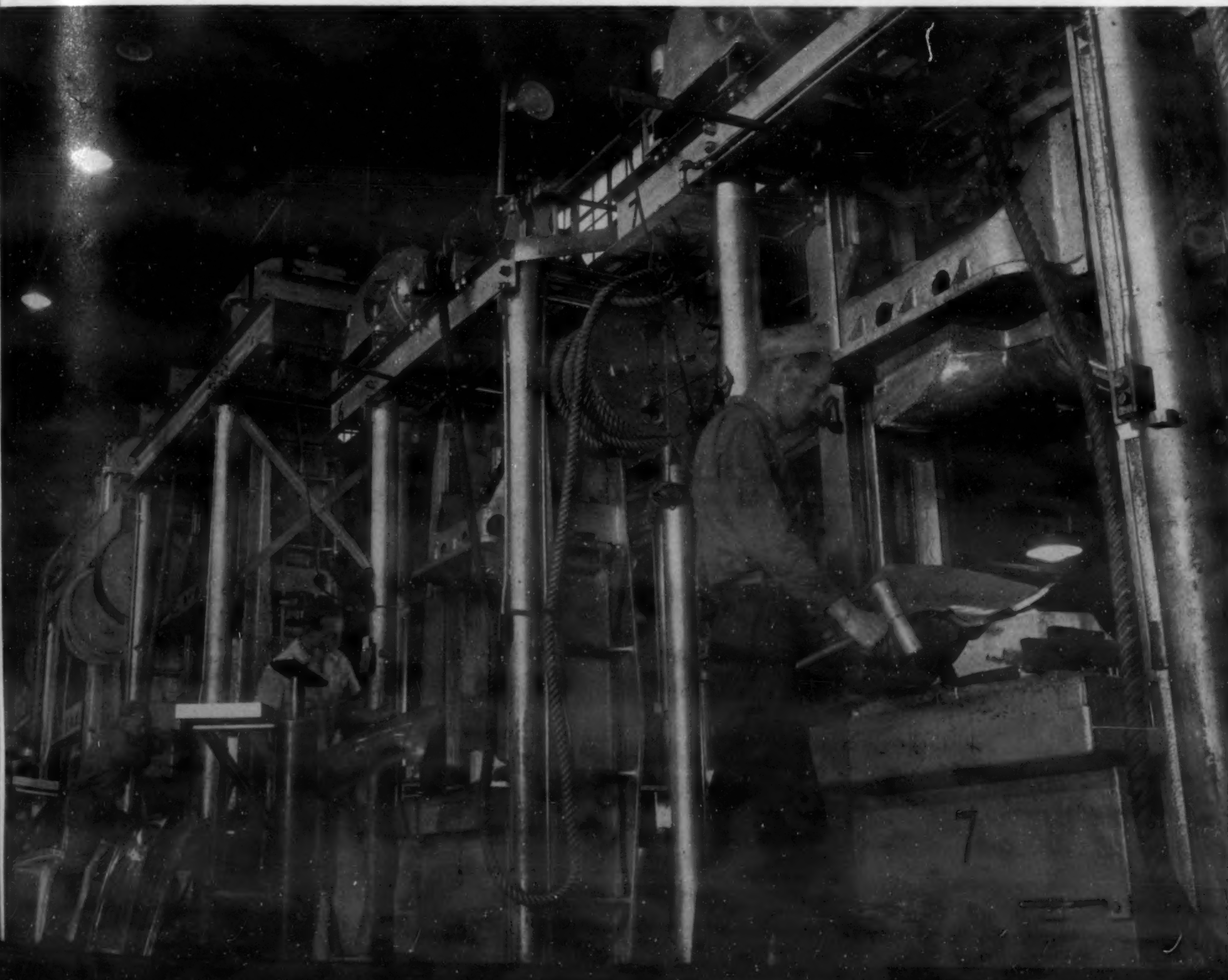
Dies of a Zinc Alloy

A considerable proportion of the dies for deep drawing are cast from soft metals and very close to required size. A primary objective is to minimize machining of the die, as only thus can its cost be made low enough to warrant the investment. Casting is simplified by selecting an alloy of fairly low melting point and one which, when it has served its purpose, can be remelted and the metal used again.

Until recently, lead and Prime Western zinc were used extensively, but as they are both rather soft and low in impact strength and in other physicals, harder and stronger alloys, chiefly those based on high purity zinc, have now come into extensive use and are largely displacing other metals. The alloy chiefly used at the Douglas plants is known as "Kirksite A," but it is quite similar to the Zamak alloys, extensively used for die casting in other industries, and also for many stamping dies in other aircraft plants. Kirksite A is a product of Morris P. Kirk and Son, Inc., but is, in fact, made under license of patents covering the Zamak alloys of The New Jersey Zinc Co.

An accompanying Table shows the relatively physical properties of Prime Western zinc and of the modern alloys which are now displacing it for stamping dies. Because of the much greater strength of the modern alloys, dies can be made lighter. They are also somewhat easier to cast, give a smoother surface requiring less finishing, are more wear resistant because of greater hardness and, if conditions require, can be repaired by welding. The dies are much stronger and harder than antimonial lead, but the

Closer view of several rope drop hammers equipped with zinc alloy stamping dies. Pressmen use wooden mallets and "dollies" in some cases for removing wrinkles from stampings prior to the final shaping in the die.



latter is still used sometimes for the "punch" or upper half of the die, largely because (since the melting point of lead is much below that for zinc alloy) the punch can be cast by using the zinc alloy lower half as a mold. In other cases, both halves of the die are in the zinc alloy.

Producing the Dies

Many of the large stampings produced by Douglas are for cowlings and fuselage covering or "skin" and many of those which require deep draws necessitate the following procedure in producing the dies:

There is first made a wooden "mock-up" or full scale model having the required contours and often having surfaces so large and of such shape that many separate stampings must be made and later assembled to reproduce its surface. To insure the correct contours, plaster casts are made against the surface of the mock-up, each covering an appropriate area corresponding to a single stamping or a portion of same. The individual plaster casts are made with hemp or similar fibre filling to increase strength. Later, some of the casts are often fastened together, or they may be used singly, as a part of a pattern.

Patterns thus made, assembled and finished with shellac, are used, just as any pattern would be, in sand molds in which the zinc alloy is cast. The pattern, of course, is shaped as may be required, to form the remaining portion of the die. After the casting has been made in the zinc alloy, its working surfaces are polished, partly by using suitable abrasive wheels on flexible shafts and partly by hand sanding and scraping. The back face of the die, which fits against the bed or head of the press, is turned off flat in a boring mill and the die is ready for use.

When a lead punch is known to be satisfactory for a particular job, it is cast in the die, but when a harder and more enduring punch is needed, it too is cast in the zinc alloy. In some such cases, the punch may be cast first and then used to form part of a mold in which the die is cast, thus saving the cost of a pattern for the die, although one for the punch is needed, of course. In such cases, the punch must be given a temporary refractory coating which is sprayed on and prevents the punch from melting and from other injury when molten metal for the die is poured around it. The coating of refractory is made of such thickness that, when later removed, it affords clearance for the sheet metal which it is to

Section of a die, cast from the zinc alloy, being polished before it is put into service

form. The die shrinks in cooling, contracting the cavities, whereas, if the punch were cast in the zinc alloy, using the die as a mold, it would shrink away from the die and not give the required dimensions.

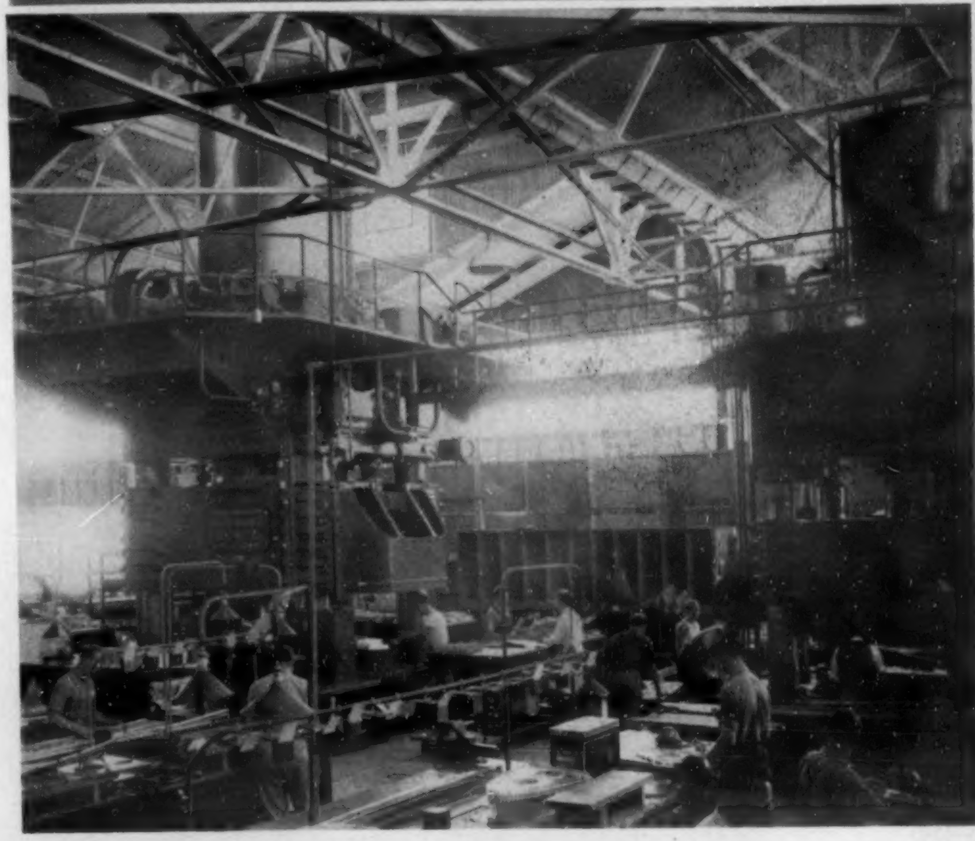
Characteristics of Drawing Dies

Drawing dies made in this manner have the same cavity shape as steel or cast iron dies but do not have pressure pads and certain other parts needed in conventional drawing operations. For this and other reasons, the dies are not used in conventional stamping presses, but in rope drop hammers. Drawing is rarely done in a single blow of the punch but in several blows and, in some instances, a progressive die having two or more stages is required. In general, however, only a single cavity die is needed, but the operator controls the number and force of the blows struck to yield a piece of the required shape, that is, one which, at the final blow, fits accurately both the punch and the die. This requires considerable skill on the part of the press operator.

In drawing the piece, he may use thick sheets or blocks of rubber, placing them by hand so that they are struck by the punch and keep the latter out of contact with the piece until it is partly or almost fully formed. During this process, the sheet metal often wrinkles and, if there is a compound bend, an effort is made to have the wrinkles come more or less parallel to the sides of the cavity rather than at an angle thereto, as then the wrinkles can be worked out as the metal is drawn in succeeding blows. Quite often, the press operator removes the work from the die when partly formed and uses a wooden mallet to work out irregularities while the work is held over a block of metal or "dolly" of required shape. This is done in part to insure the required shape, but also, in some cases to remove wrinkles which, if allowed to remain, might mark the die, causing a roughness which would prevent making a smooth finished piece. Although the production of a single stamping may require several minutes, if the part be a difficult one to draw, the process represents a great improvement over earlier methods in which the entire piece was hammered to shape and gradually fitted over a wooden form.

The Guerin Process

The foregoing applies to drawing operations, as distinct from much simpler blanking and forming operations, most of which are done by the Guerin process, developed after long experimental work, by Henry E. Guerin, factory manager of the Douglas Santa Monica plant. This process is carried out chiefly in hydraulic presses, the largest of which has a capacity of 5000 tons pressure, and often results in producing many quite different stampings in a single stroke of the press. Although some drawing (involving a considerable flow of metal) is done in the Guerin process, it is chiefly of a type involving rather shallow draws, usually much shallower than is done in the drop hammer dies referred to above. But it is frequently advantageous to preform by the Guerin process and finish in drop hammer dies.



Top: Rotary shears shown here are employed for trimming flash from some stampings.

Bottom: Two of the very large hydraulic presses which produce stampings in large quantities by the Guerin process, sometimes over 50 parts in a single stroke of the press.

Rubber Replaces Positive Punch

In the Guerin process, rubber is commonly substituted for a positive punch, the rubber being confined in a metal box or container and usually attached to the head of the press. Walls of the box extend below the rubber and mate with a pressing block

Applying a large blank to a combination forming and piercing die used in the Guerin process.

Stamping as it appears after piercing and forming in a zinc alloy die.

Blank, previously cut to size and notched in a blanking operation and afterward drilled with rivet holes, being applied to a zinc alloy forming die used in the Guerin process.

thereby confining the rubber and causing it to flow, with uniform pressure in all directions, around the sheet metal which is thus sheared and/or formed to the shape of the die which lies on the bed of the press.

If only blanking is to be done, the die usually consists of a Masonite (hard compressed fibre) block $\frac{3}{8}$ in. thick faced, with a sheet of chromium-molybdenum steel of such shape as to provide and hold a keen cutting edge. If the part be blanked and requires only flanging, the die can be merely a Masonite block of such thickness as to permit the flange to be formed. If the shape is complex or involves both shearing and forming, the die is sometimes cast from Kirksite and the cutting edge is then ground

or filed. The edge secured is satisfactory when runs are short.

Dies can be either female or male or a combination of the two, but small holes such as those for rivets, are usually drilled rather than punched. If considerable forming is required, the die is usually cast from Kirksite, commonly employing a wood pattern. Some drawing can be done with dies made in the same way, but the draw is usually much shallower than that made in drop hammer work, and the punch (or upper half of the die) is still the confined rubber, as for other work by the Guerin process.

Some Advantages of the Guerin Process

A great advantage of the Guerin process, in addition to the important saving in die cost, is that, since the punch is rubber and is forced to conform to the die, no exact registry is involved. Consequently, many dies can be and usually are grouped on the bed of the press and are used with a single sheet of the required metal to produce simultaneously as many stampings as there are dies. The dies are nested in such a way that scrap is reduced to a minimum. In large presses, more than 50 pieces are sometimes blanked at one time, the blanking dies being fastened to a gang plate of 3/32-in. steel.

In the case of large presses, loading, unloading and handling are greatly facilitated and the press is used to greatest advantage by providing it with carriers on tracks so arranged that, while one set of dies is being run onto the bed of the press, the press is being closed and opened and the set removed, three other sets on the other three sides of the press are being loaded or unloaded in preparation for transfer in turn on the press bed. As the bed of the press is at normal table height and loading tables are on each of four sides, many men can work simultaneously at the loading and unloading operations. This makes it possible to keep the press busy and to turn out a total volume of work which justifies the investment in a press of extremely large size.

Aluminum and Magnesium Sheets Used

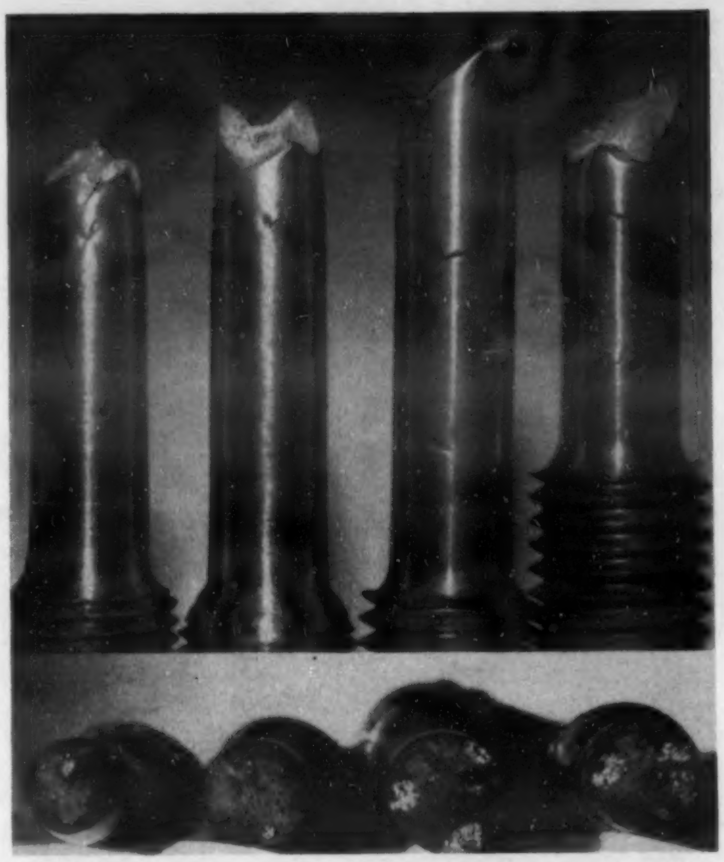
Blanking operations on soft aluminum sheets up to 0.051 in. thick have been done and forming operations can be performed on sheet of the same material up to 3/16 in. thick, providing the flanges to be formed have sufficient area to enable the pressure of the rubber to effect the bend. Combination blanking and forming is done on soft aluminum sheets up to 0.040 in. thick. Thin gages of stainless steel can also be handled, especially where much of the blank remains flat, and even quarter-hard stainless steel can be formed in some shapes. Magnesium alloy sheets which require heating for forming have been handled by using heater plates either on the loading table or on the pressing block.

Although the Guerin process is of course not universal in its application, it has proved exceedingly useful and economical in the production of many thousands of different parts entering into the construction of Douglas planes and has resulted in a great reduction of hand work as well as in production on an interchangeable basis, which is so necessary even when the quantities of individual parts are not large. The process fills a gap which formerly existed between mass production in large quantities with expensive tooling and fabrication in which hand operations are dominant.

Table Comparing Physical Properties of Sand Castings Made in Prime Western Zinc and in Modern Zinc Alloys as Used in Casting of Stamping Dies

Physical Property	Sand Cast Prime Western Zinc	Modern Sand Cast Zinc Alloy
Tensile strength, lbs. per sq. in.	5,300	35,000 to 38,000
Impact strength, ft. lb.; ¼ x ¼-in. bar, Charpy 40 mm. span	less than 1	2 to 4
Compressive strength, lbs. per sq. in.	no data	60,000 to 75,000
Melting point, deg. F.	787	717
Solidification shrinkage, in. per ft.	0.125	0.140
Weight per cu. in., lb.	0.27	0.24 to 0.25
Elongation, per cent in 2 in.	no data	3.0
Brinell hardness No.	30 to 60	80 to 107

Stamped rib as it appears after forming (flanging) in the die seen back of the piece.



BY FRANCIS B. FOLEY

Superintendent of Research
The Midvale Co., Nicetown, Philadelphia

The author, at our solicitation, has contributed a valuable discussion to a problem which is of vital interest to any preparedness and defense program. He has drawn from his experience as a metallurgist for the U. S. Bureau of Mines, collaborating with the Ordnance Department of the Army during the last war, in the investigation of "flakes" and "cooling cracks" which abounded in gun steel produced in certain plants during the rush period of production. To this he has added more recent observations.

He has merely hit the high spots, he says, and has not pretended to go into the details of many investigations which have been reported in the technical press from time to time during the last twenty years.—The Editors.

—A Problem in Ordnance

Flakes and Cooling Cracks in Forgings

Fig. 1. Above: Broken tensile test specimen showing flakes. From a 2X mag. Two on left are longitudinal bars; the two on the right tangential bars from the same forging.

PROBABLY THE MOST INSIDIOUS DEFECT which developed in the manufacture of ordnance during "World War I" was the one to which the name "Flake" was given. This defect got its name originally from its resemblance to a snowflake and in fact the first name given to it was "Snowflake." They were first noticed in the fractures of tensile test specimens, appearing as a white area (Fig. 1) in the otherwise normal fracture and they were always accompanied by low elongation and reduction of area of the specimen. Rarely if ever did a "flaky" tensile specimen meet the required 18 per cent elongation in 2 in. Deep-etching of sections from forgings showing such defective tensile specimens was at first not resorted to but later on, when such sections were deep-etched, the defects could often be detected as fine cracks eaten out by the acid and confined to an area below the surface, the surface metal for a depth of perhaps 1 in. to 1½ in. being sound.

Acid and Basic Steel Compared

Prior to the period of World War I there had been no trouble with defects of this kind in ordnance manufacture or if there was any such trouble it was so slight as to pass unnoticed. Certainly it never attained anything like the epidemic proportions which, in one case in the writer's experience, caused the loss of 80 per cent of production. Lack of experience in melting and forging large sections of alloy steel was no doubt responsible for most of the trouble. Prior to this period much of the ordnance steel produced had been melted in acid open-hearth furnaces in which this defect rarely if ever occurs. The basic electric furnace was a comparatively new melting unit and it produced the greatest amount of "flaky" steel.

It has developed since that there is considerable authority for the statement that acid steel is less prone than basic to develop defects of this type and the writer has yet to encounter any at all in acid steel. Aside from the use of basic steel for ordnance there is little doubt that lack of experience played a large part in the difficulty of producing flake-free alloy steels of large section. It is also true that experienced ordnance manufacturers had over a period of years developed mill practices which had kept them out of difficulties of this sort.

Two Types of Flakes

Many different types of defects have come to be called "flakes." There are, however, two principal types: One is the original "flake" or "snowflake" having the appearance one would produce by cutting out a small circle or oval of very thin silver foil and pressing it tightly on to the fracture surface of quenched and drawn nickel steel or nickel-aluminum steel. The structure was not much if any coarser than the balance of the fracture and the "flake" stood out on account of its brightness alone. The defect was larger on the fracture of transverse bars (the two fractures on the right in Fig. 1) than on longitudinal test bars (the two fractures in the left in Fig. 1). In pulling a test bar the defect did not show up until the load had exceeded the elastic limit after which the tears or pulls appearing in Fig. 1 develop, the bar finally breaking through one of them. There is some evidence that this type of "flake" is not a discontinuity. The following record of tests indicates that this may be true:

Average Physical Properties

	No. of Bars.	*Tensile strength lbs. per sq. in.*	*Elastic limit lbs. per sq. in.*	*Elong. per cent*	*Red. of Area per cent*
Flake-free bars	182	101,580	68,268	19.51	37.53
"Flaky" bars	152	97,000	68,120	11.59	20.48

The average elastic limit of 182 good bars is the same, within experimental error, as that of 152 defective bars. The tensile strength of the "flaky" bars is lower than that of the good bars. This may be explained by supposing the "flake" not to be a discontinuity which would cause a sudden failure at low load but an area of low ductility which does not elongate, as does the normally tough metal surrounding it, after the elastic limit has been passed. These brittle areas part, leaving the load to be sustained by the tough surrounding metal up to the breaking load.

Eliminating Flakes by Heat Treatment

An attempt to eliminate these "flakes" by heat treatment produced the results shown in the Table. The properties in the Table are averages of results from two test bars. All came from a 1¼-in. thick, 15-in. dia. disc which had been cut along two diameters to produce four quarters which were treated as shown in the table. The area of the "flakes" was measured with a planimeter on photographs of the test bar fractures. A general decrease in the area of the "flakes" with corresponding improvement in tensile strength and elongation resulted from the increased degree of refinement produced by the treatments. Discontinuities would not be expected to respond to treatment in this

Table of Results of Eliminating Flakes by Heat Treatment

Treatment	*Tensile strength, lbs. per sq. in.*	*Proportional limit, lbs. per sq. in.*	*Elong. per cent*	*Red. of Area per cent*	*Flake*
As received	84,430	51,435	3.75	14.25	64.1
1400 deg.-2 hrs. water; 1200 deg.-2 hrs. slow	93,460	75,090	5.5	17.0	22.8
1500 deg.-2 hrs. water; 1400 deg.-2 hrs. water; 1200 deg.-2 hrs. slow	95,545	65,500	6.75	13.5	16.4
1600 deg.-2 hrs. slow; 1500 deg.-2 hrs. water; 1400 deg.-2 hrs. water; 1200 deg.-2 hrs. slow	101,925	77,465	11.5	24.2	9.7

manner. The composition of the steel was C 0.40, Mn 0.52, P 0.027, S 0.027, Si 0.12, Ni 2.99, and Cr 0.14 per cent melted in a basic electric arc furnace.

Effects of Overheating in Forging

Defects of this type may be caused by overheating in forging. Measurements of the temperatures to which ingots were heated in a plant where this defect was prevalent showed that the bottom end was being heated to as high as 2600 deg. F. and the top end to about 2200 to 2300 deg. F. Two forgings were made from each ingot. Little trouble was experienced with "flakes" in the forging from the top, but they were quite prevalent in the forging from the bottom end of the ingot. When a maximum temperature of 2100 deg. F. was set for heating the ingot, "flakes" practically disappeared.

Cooling Cracks

What seems to have been another type of defect, although it also was referred to as a "flake," appeared in similar metal in another plant. It was the type most accurately described as a cooling crack. Etching and microscopic examination showed it to be a crack. Test bars broke before attaining their elastic limit, without elongation or reduction of area. These cracks were found to follow the grain boundaries in the forging before heat treatment (Fig. 2).

One of the striking characteristics of these cooling cracks was their association with large grain size in the forging. This large grain size is shown in the photomicrograph, Fig. 2 at 100 X, but was brought out more strikingly perhaps in the photomicrographs

Fig. 2. Cooling crack following grain boundary of large grain of specimen from untreated forging. Slightly reduced from a 100X mag.

of the entire section of test bar ends as shown in Figs. 3 and 4 at 7 X. In sectioning through a defective area a large grain size like that in Fig. 3 was always found, whereas sound areas in which no cracks were present had the grain size of Fig. 4 or finer.

Slow Cooling a Cure

It is now well known that a cure for internal cooling cracks, whatever their cause may be, is slow cooling of the forging in a particular range of temperature, probably from 750 down to 400 deg. F. The temperature range in which internal cracking occurs is probably different for different analyses of steel. Carbon steels are not very susceptible to the formation of this type of defect, but they are not wholly immune if "shatter cracks" and "transverse fissures" in rails and locomotive tires are correctly assumed to have their origin in defects of this type. Such defects have been practically eliminated by the use of a controlled rate of cooling.

While relatively high carbon steels may be susceptible to the formation of cooling cracks, the greatest trouble has been experienced with low alloy Cr, Cr-Mo, Ni-Cr and Ni-Cr-Mo steels. These are steels with air-hardening tendency. Susceptibility appears to start in sections of 2 to 3 in.; smaller sections rarely if ever developed them under normal conditions. It is also true that they are not developed in the outer one inch or so of surface metal.

These facts regarding size do not appear to fit in logically with the use of a slow cooling rate for their elimination since the smaller sections and the outer layers which cool most rapidly do not develop them. However, there are explanations of this apparent anomoly which can be developed from the theories advanced for their formation.

Effect of Hydrogen

Recent literature attributes internal cooling cracks, for which the name "flake" is commonly used, to the presence of hydrogen in the steel. This conclusion is arrived at largely as a result of finding cooling cracks to occur inevitably after appropriately cooling steels into which hydrogen had been purposely introduced. There seems to be no doubt that hydrogen, in sufficient amounts, will cause cooling cracks and that, even in such cases, controlled cooling will prevent their occurrence. It has been shown that the liberation of hydrogen during cooling can build up pressures sufficiently high to rupture steel. The absence of cracks in the outer layers is attributed to the fact that hydrogen escapes and, as the surface cools more rapidly than the interior of the large sections, it is strengthened and the stresses, developed in the weaker interior by the liberation of the gas, are relieved by local cracking.

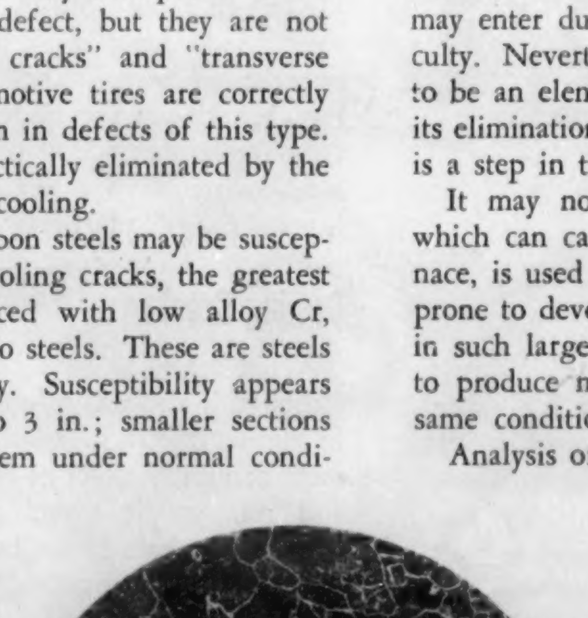
It has not been shown, however, that hydrogen is the only element which will render steel susceptible to this behavior and there is a shortage of data, if indeed any exist at all, to show conclusively that steels with the normal content of hydrogen which may enter during melting can account for the difficulty. Nevertheless, since hydrogen has been shown to be an element which can produce cooling cracks, its elimination as far as is practicable during melting is a step in the right direction.

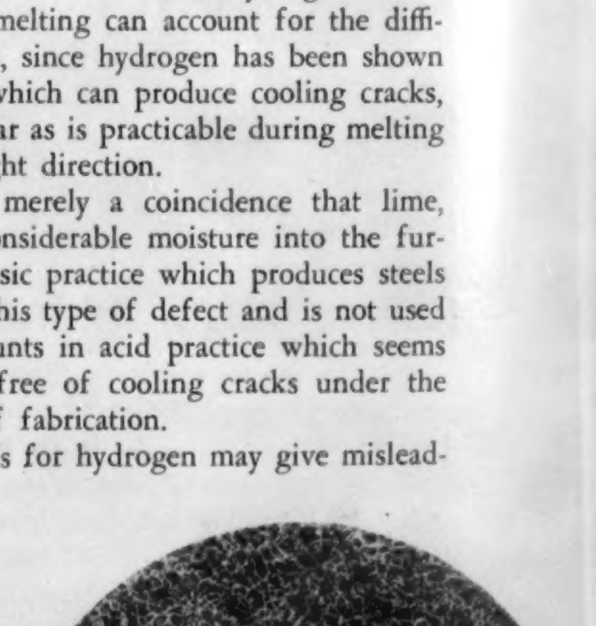
It may not be merely a coincidence that lime, which can carry considerable moisture into the furnace, is used in basic practice which produces steels prone to develop this type of defect and is not used in such large amounts in acid practice which seems to produce metal free of cooling cracks under the same conditions of fabrication.

Analysis of steels for hydrogen may give mislead-

Fig. 3. Left: Photomicrograph showing large grains which accompany cooling cracks. 7X.

Fig. 4. Right: Photomicrograph of finer grain of specimens containing no defects. Specimens in both Figs. 3 and 4 are from untreated forgings. 7X.





ing results. The fact that a heat of basic steel which developed cooling cracks was found upon analysis to have 0.00006 per cent H and an acid steel of the same analysis and which did not develop them had 0.00005 per cent H is not conclusive evidence that hydrogen had nothing to do with the case. These steels had been heated and cooled many times in the course of forging and heat treating so that much of the hydrogen may have escaped. An analysis of the gases in the molten metal in the ladle or in the ingot might have given entirely different results. The added chances of picking up hydrogen in the arc of the electric furnace may explain why the basic electric arc furnace seems to produce metal most susceptible to cooling cracks.

Grain Size and Its Effect

Undoubtedly grain size plays a large part in the development of cooling cracks. It is the operations which result in the coarsest grain structure which produce the greatest tendency toward development of cooling cracks. The coarsest grain structure exists in the ingot itself. It is not often that ingots are sectioned and etched to determine whether or not cracks exist in their interior and this is not of practical importance for, even though cracks be present at this stage, they readily weld during hot working and produce a perfectly sound product if handled properly after forging. Fig. 5 shows cooling cracks in a section from the top of a 19-in. corrugated ingot which produced forgings that were satisfactory in every respect. In fact there is no stage at which hot working will not fully correct this sort of defect. Next in order of grain coarseness is the forging. It is at this stage of production that inspection discloses defects that have occurred during cooling. If they are not produced at this stage, they will not occur during subsequent treatment. After normalizing, which refines the forging structure, cooling cracks are not found, unless they were present prior to normalizing, although the rate of cooling in this operation is one that would produce cracks if applied to the coarser forged structure.

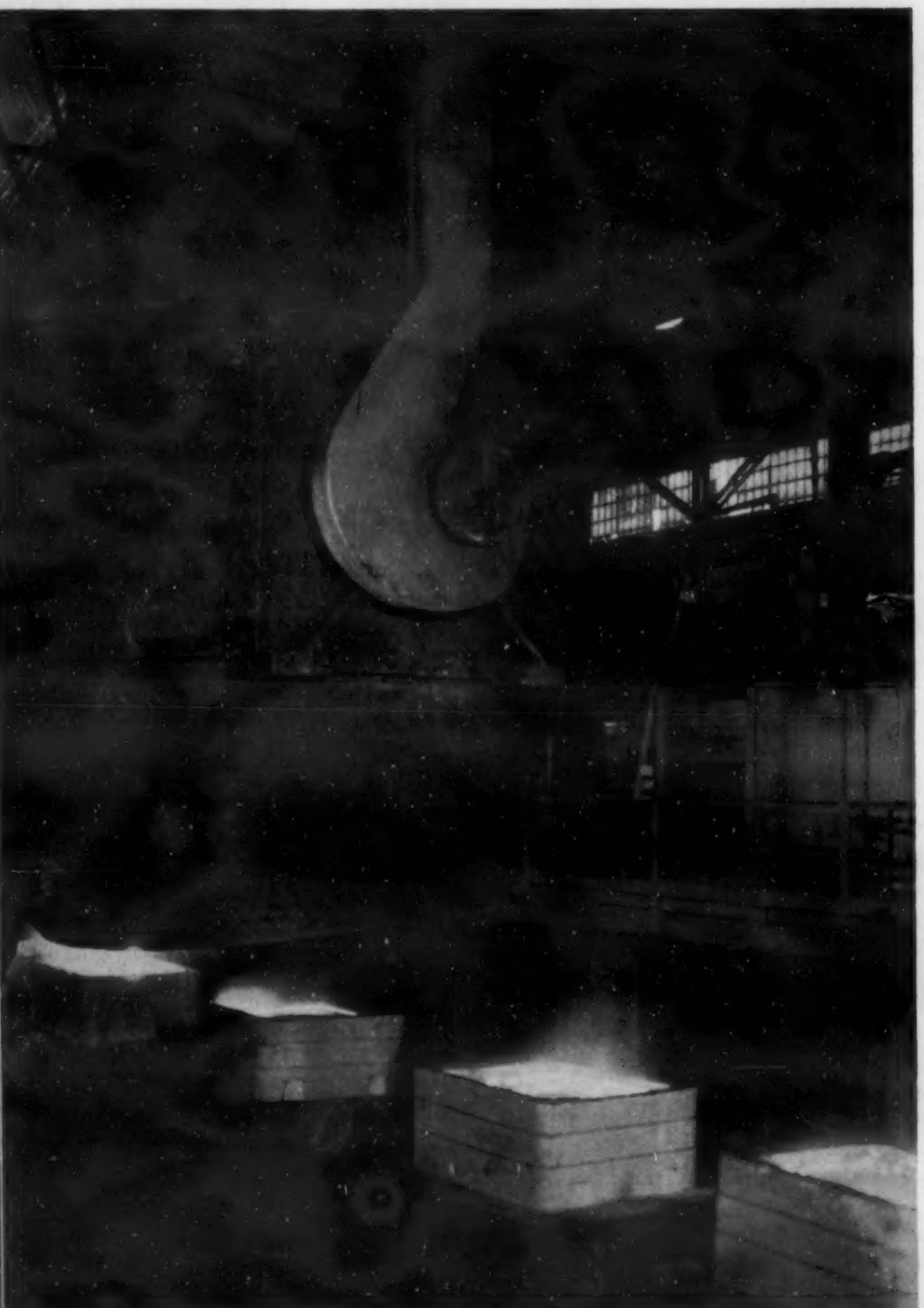
One may say that the amount of hydrogen present decreases as the metal progresses from the ingot stage through to the normalized forging. Nevertheless, the illustrations given in Figs. 3 and 4 indicate that grain size in the forging itself, prior to refining by normalizing, may have a marked effect and it has been demonstrated in the case of 1 per cent Cr, 1 per cent C bearing steel, susceptible to this defect, that forging and finishing at low temperatures retarded the formation of cooling cracks. The production of a fine grain by carrying hot working down to a low temperature is therefore probably favorable to the elimination of "flakes."

Grain-size may also account for the absence of defects in the surface layers since the outside of the forging is more effectively worked at a lower temperature than the interior, even in the case of relatively hot finished forgings, and as a result is finer grained. Steels most prone to the development of cooling cracks have a tendency normally to be air-hardening and a coarse grain increases this tendency. The absence of cooling cracks in sections smaller than 2 in. could result from the finer grain produced in working the entire section at a low temperature.

A correlated abstract by Zapffe and Sims has appeared in recent issues of METALS AND ALLOYS [May, June, July and August] on "Hydrogen, Flakes and Shatter Cracks" in connection with which a most complete bibliography appears on the entire subject. It is therefore unnecessary here to re-survey the literature on the subject. One derives from all of it that controlled cooling, following forging, is a necessary step in the handling of "flake-susceptible" steels and in this connection one must not lose sight of the fact that the end of the forging which has been finished and is extending out of the furnace while the other end is being re-heated for finishing may develop cooling cracks if its temperature falls rapidly through the danger zone. It should also be remembered that the ends of a forging cool more rapidly than the middle so that, if burying be resorted to, the ends of the forging are best buried first. In melting, lime and the rust on scrap can take up and retain considerable moisture and thus introduce hydrogen into the bath.

Fig. 5. Etched section from the top end of a 19-in. corrugated ingot of C 0.10, Ni 3.90, Cr 1.40 per cent steel showing cooling cracks. Center is bottom of primary shrinkage cavity or pipe. From a 0.4X. mag., slightly reduced.

Electric Furnaces and National Defense



by W. M. FARNSWORTH and M. J. R. MORRIS

Supt., Canton Steel Div., and Chief Metallurgist, Massillon District, Republic Steel Corp, Respectively

Armor plate, made from electric furnace steels, "has been shown to be far superior to that of steels made by the older methods" is a concluding statement of the authors of this article. "Armor plate made in the electrics has under test shown the greatest resistance to shell fire yet displayed."

Besides heavy armor plate for battleships and cruisers, the new type of war technique is calling for medium and light grades for tanks, large and small; for the decks of naval vessels and their auxiliaries, both due to the development and use of the modern "dive" bombers; for the protection of certain parts of airplanes, and so on.

Undoubtedly electric steel will be a large factor in the production of modern armor plate as well as other military steels. The authors call attention to their company's equipment to meet this condition.
—The Editors.

FROM THE VERY OUTSET of the present national emergency, it has been obvious that the construction of a two-ocean navy, plus the wholesale mechanization of all our means of land defense, would involve some industries considerably more than others—and the steel industry in particular.

Armor Plate Yesterday and Today

By and large, in "World War I," armor plate was confined in its application to naval vessels, to the limited number of tanks then available, and as protection for land batteries. Today's highly mobile type of warfare has abruptly changed all that. Gone, apparently, are the trench-type tactics of 1914 to 1918. The use of tanks has been multiplied a thousandfold. High-speed transportation of sizable amounts of infantry in light-armored trucks has become the new order of the day.

The weight factor has kept armor plate from becoming much of a factor in the construction of aircraft, except for the limited protection of pilot seats and some work on gas tanks. On the other hand, the development of the modern bomber has created the need for immediately increasing the armor plate protection available on the decks of naval vessels and auxiliaries. The appearance of the deadly "dive" bomber has undoubtedly prompted equally sweeping

Left: Republic Steel's role in the armor plate program is as a maker of electric furnace steels and a supplier of forging bars. Subsequent treating and fabricating operations are handled by other manufacturers. Tentative armor plate capacity has been set up at 7,500 tons per month, requiring approximately 10,000 gross tons of electric furnace ingots.

revisions in the amount and kind of armor plate to be used on the tops of tanks, particularly the larger tanks or mobile "land fortresses," which were used so effectively by the Germans in consolidating their rapid flanking advances so successfully against the combined French and English armies on the continent.

So far as the United States is concerned, Hitler's march to world conquest, if indeed such is his intention, may in the last analysis be stopped more by the ability of America's metallurgists and steelmakers to produce in quantity, in quality, and with speed, the new sinews of war, than by the valor of American youths on the field of battle.

The impression has unfortunately become quite widespread that our great American industries are able to—or could under compulsion—get into volume production on any and all phases of the national preparedness program practically overnight. Nothing, of course, could be farther from the truth. Many industries before they can handle their share of re-armament work must practically re-tool their plants or otherwise re-arrange much of their existing machinery, which may take months to do.

Electric Furnace Armor Plate

However, there is one field where, perhaps more than almost anywhere else, circumstances have combined to make available both the physical capacity and the necessary trained personnel to function quickly and effectively on matters of national defense. That is the field of electric furnaces and the production of electric furnace armor plate.

Anyone who has had any experience with making steel in the electric furnace knows that it is an operation which cannot be mastered overnight. We are more than fortunate, therefore, that the peace-time demands of the last 25 yrs. in this country—since 1915 and World War I, in fact—have been of such a nature as to encourage and to promote the development of the necessary skills and techniques which are required to produce the fine alloy steels which are now so urgently needed in aircraft, tank, and armor plate work.

Extensive and unremitting research into alloy steels has been in progress for nearly a quarter of a century in some of the steel companies which today constitute the Republic Steel Corp. First, of course, came the work with the fine bearing steels. This was followed by research into the early aircraft alloys of World War I days. The problems involved in making steels for racing engines were next tackled. Most familiar to many, of course, was the development of the stainless alloys. And today we are back once more to a large-scale consideration of armor plate. A direct result of this long-term research has been the building up of a well-trained operating personnel, as well as adequate electric furnace facilities, which are now available to meet the present emergency.

Electric furnaces today are making possible the production of the finest alloy steels known to man—and on a scale of speed, uniformity, quality, and ability to resist present-day fire power, unknown in World War I.

Resistance to Shell Fire

While it is not feasible, of course, to publish any comparative figures for the current volume of armor plate which is being made in electric furnaces—as contrasted with older methods—it can be said with authority that the armor plate made in the electrics has under test shown the greatest resistance to shell fire yet displayed.

The general utility of electric furnaces in the national preparedness program concerns itself, of course, with their ability to produce cleaner, higher quality, more uniform alloy steels. Increasing peacetime demands from such industries as the automotive for more and more special steels, steels that had literally to be "tailor-made" to particular specifications, created problems for the metallurgist and the steelmaker which in many instances could be solved only by the use of the electric furnace process. In fact, there have been instances where a steel, which had been made successfully in the open-hearth for years, now has had to be transferred to the electric furnace because of more rigid specifications and the requirement of greater uniformity from one heat to the next.

Electric Furnace Technique

The operation of electric furnaces has always required the highest calibre personnel, men with extensive electrical as well as metallurgical training, and years of actual operating experience. In Republic, for example, we have a number of electric furnace operators who have been in the same work—even on the same job—for upwards of 20 yrs. or more.

The Liberty motor, product of some of the country's most skillful engine designers, and the "last word" in an airplane power plant in 1918, was made possible by the early "aircraft quality" steels that came from electric furnaces. Much research had preceded even these steels because Republic's predecessor companies, through research, already had become the largest producers of fine alloy steels for the automotive, railroad, and petroleum industries. Today, every American-made plane contains alloy steels produced by the electric furnace.

Several types of electric furnace construction are in use. Of these, the predominating types are the conventional Heroult arc and the high-frequency induction furnace. Low-frequency induction furnaces are few in number. One of the largest of them (6 tons) is in our Canton plant.

Ten Electric Furnaces

Within the past year, Republic has substantially increased its electric furnace capacity. Including its two newest 50-ton electrics which are about to be put into operation, the Canton plant now has three furnaces of 50-ton capacity, two of 25-ton capacity, three of 15-ton capacity and two of 6-ton capacity. All basic-lined, these electric furnaces are used to produce special carbon steels, alloy steels of all analyses, and low- and high-corrosion-resistant alloys. Exclusive of armor plate steels, the largest production of the furnaces includes the anti-friction bearing steels (high-carbon chromium and low-carbon alloy), aircraft alloy steels, and semi- and full-corrosion-resisting alloy steels.

To provide the working space necessary for the newest Heroult 50-ton furnaces installed in the Canton plant, a modern, well-constructed open-hearth was torn down. The new furnaces have single 12,000-kva., three-phase transformers, but peaks up to 16,000 kva. cause no trouble. The highest voltage used is 260. Lower taps are 250, 230, 200, 150, and 135 volts—with 8,000 kva. available on the lowest tap. Control is automatic at any desired setting. Especial attention has been given to making the furnaces tight against air infiltration. The bottom is a monolithic lining of sintered periclase, while the upper structure is of the conventional magnesite and silica brick. Charging is handled entirely by machine.

The first of these three furnaces, installed several months ago, has been making large amounts of 5 per cent nickel and chromium-nickel-molybdenum aircraft steels. It also handles 16 per cent Cr and 18 and 8 stainless—both with either 0.06 per cent or 0.12 per cent C maximum. The 18 and 8 products, alloyed with titanium, molybdenum or columbium, have been produced with complete success. The furnace operates entirely from cold stock, each heat taking about 8 hrs. Normal output per month per furnace will probably exceed 5000 tons, all of it special alloys for specific applications.

Electric furnaces from the very outset have been considered synonymous with the production of the highest quality alloy steels. Unfortunately, however, the early opinion, more or less widespread in the industry for many years, was held that so long as electric furnaces were used in the production of these "fussy" steels many other factors which had to do with the ultimate quality of the product could be ignored. The ability of the electric furnace to attain high temperatures, to afford maximum control over oxidation, to provide unusual flexibility on pouring, and to handle special and complicated analyses, overshadowed, for a time, the fact that many problems remained which could only be solved as actual experience, acquired literally on the "firing line," could be accumulated.

Electric Steel for Armament

Because it was noted very early that electric furnace steels possessed superior physical properties, the electrics were quickly given the production of certain types of special steels, tool and ordnance steels, armor plate and gun steels.

However, with the program of world-wide disarmament which was undertaken by common consent of all nations in the early "twenties," and the tremendous volume of production which developed during the same decade with the growth of the automotive industry, the proportion of electric furnace steel going into armament became a smaller and smaller part of the total. With its decrease, the contribution of the electric furnace in one of its initial roles as a producer of armament was, therefore, more or less forgotten.

The making of high grade steels is an art, rather than a science. The amount of effort which has been put into the production of high grade steels would fill thousands of pages. No one factor appears to solve the problems which must be met from day to day. Many of these problems have been successfully tackled, yet the operators of electric furnaces feel there is much still to be learned, particularly as the demand for steels of more or less "tailor-made" quality continues on the increase. The new dictates which are constantly being handed to steelmakers, the ever-changing standards, and the demands which industry at large, and designers in particular, are

Alloy additions, similar to the one being made here, must be closely controlled to produce the fine alloy steels now so urgently needed in aircraft, tank and armor plate work.

An electric furnace operator must be a combination of rare intuition and patience, and possess extensive electrical as well as metallurgical training. He makes the "fussy" steels, measuring and adding the alloying elements with an accuracy which would put even a prize cake maker to shame.

making, are in all cases becoming more and more rigid. The man in the street has little comprehension and certainly less appreciation of the headaches which have been lived through and are being encountered almost daily by the metallurgist and the steelmaker in overcoming what to the onlooker may well appear to be relatively simple difficulties.

Bearing and Aircraft Steels

Most plants using electric furnace equipment have been concerned with and trained primarily on making some one product of major importance marketwise. For example, we in the Canton-Massillon district of the Republic Steel Corp. have been particularly concerned with and have derived considerable experience and training extending over a number of years in the making of ball bearing steels of the chrome type. They are the "Tiffany" of steels and have led the way in quality and excellence in the industry for years. The making of these steels has required a large investment in time, effort, equipment, and personnel over a period of years. In their develop-

ment it has been necessary to conduct extensive studies of ingots, slags, etc., and the research work is by no means yet ended. In fact, the progress which we have made so far has simply convinced us that our understanding of the electric furnace and its products has scarcely more than begun and that, by and large, we had better assume that we still know but a small part of what will some day represent the sum total of available knowledge of the art. Certainly up until 1927, the generally accepted belief in the trade that simply because a steel was produced in the electric furnace, it of necessity represented the "hall mark" of quality was not necessarily supported by the facts. This has been borne out by our own experience—as well as by the recorded experience of others.

Metallurgical Problems and Training Operators

Scarcely had we gotten our breath in the research on bearing steels than we were plunged into a study of modern aircraft steel requirements. Fortunately, the production demands in this category of special steels were slower to develop and did not reach any marked crescendo until around 1935 when such new and special tests as the Magnaflux were developed.

We had the problem of going at the fundamentals of the electric furnace practice in an endeavor to explain the observations which were being made by our keenest operators, the men who had worked these instruments and equipment for years. At the same time, we also had the problem of training more men in furnace operations as well as in the metallurgy of steels. These were not simple problems, although boiled down they looked simple. An electric furnace operator, we found, is not made overnight. He is a unique combination of intuition and patience.

We have, as a consequence, had to expend considerable time and money on solving these two problems, believing that only as they were solved could real progress be registered. We furthermore installed a pilot electric furnace plant to handle 50 to 300-lb. melts as a means of studying the attributes of the steels we were interested in. The investment in this supplementary equipment has proved invaluable.

We have also developed a considerable background of knowledge through extensive exploration in the gas analyses of steels, being the first steel company in the country to set up such research work.

All of the foregoing efforts have helped us to get rid of some well established opinions which had become widespread and general in their acceptance, both in the thinking of steel men and in the current literature of the day. For instance, around 1923 we had a problem in the making of the everyday, common variety of shovel. On being tackled, this taught us that alloys when added to steels require definite treating and handling. The experience gained in the handling of plain carbon steel is not sufficient to satisfy the requirements of handling steels with alloys added. Using the microscope at relatively high power and supporting the findings of this with the X-ray explained our difficulty. While we do not use the X-ray in the role of everyday equipment, we do make use of it regularly on special work.

Electric Furnace and National Defense

But what has all of the foregoing to do with the present problem confronting the country? What has it to do with the contribution of electric furnaces to national defense?

Briefly, this—the making, shaping, and processing of steels used successfully in armor plate are not matters of happenstance. Their successful application is the result of much patient work and the getting and keeping together of a highly trained personnel, and the supporting of this trained personnel with adequate production facilities and capacities, as well as the necessary technical and research equipment.

Under the circumstances, and considering the nature of our "baptism" into the "fold" of electric furnace operators, we in all modesty believe that we are no novices at the game. We entered it coldly and coolly as a definite undertaking two decades ago and since that time have not only produced a creditable part of the total production of these special steels, but also have handled the bulk of the armor plate used on scout cars, etc., made in this country.

With these fundamental problems successfully solved, it becomes a relatively simple matter to meet present-day demands. Therefore, the increasing of our electric furnace steelmaking capacity to a total of 11 furnaces, four of which are of 50-ton capacity, is a logical development of our experience in their operation which extends back nearly 25 yrs.

At present Republic is the largest maker of electric furnace steels in the country. Since the quality of these steels, and particularly the armor plate, from all tests made to the present time, has been shown to be far superior to that of steels made by older methods, we believe we are ready to handle whatever demands may be that lie ahead of us in the program for national defense.

World War I gave the electric furnace its first big push into production. Bearing steels and stainless subsequently enlarged the field for action. The present urgent requirements inherent in the program of national defense may well crowd the electric furnace into such volume of production as not all the peace-time demands of our peace-time industries have yet equalled.

A Bell Airacuda multi-engine fighter, pusher type plane with two forward firing 37 mm. cannons of 240 rounds a minute. Speed over 300 m.p.h.

The Airplane Laboratory and National Defense

by ROBERT C. WOODS

Physicist, Bell Aircraft Corp., Buffalo, N. Y.

BECAUSE AMERICA IS DETERMINED to give her pilots the safest, fastest, and most flyable planes in the world, metallurgical engineering has probably attained a more important position in our aircraft plants than in any other industry.

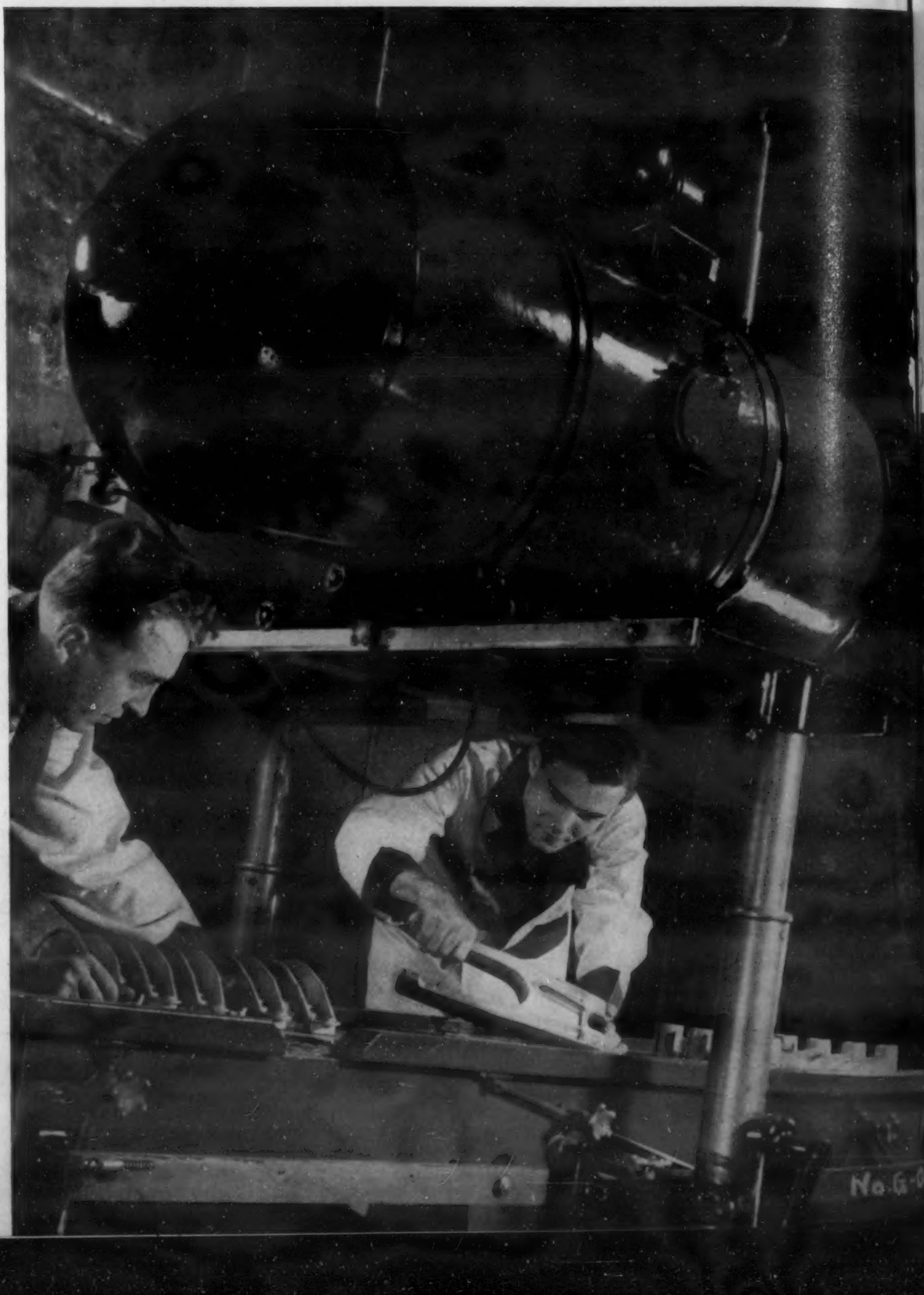
For the rigid inspection of all incoming materials and for investigation into unexplored metallurgical fields, the Bell Aircraft Corp. of Buffalo, N. Y., has recently installed a complete aircraft testing laboratory equipped with the latest scientific instruments for engineering research and manned by a staff of skilled workers. Here plane fittings are routinely examined by X-rays for cracks, pinholes, porosity, gas pockets, slag inclusions, and pronounced chemical segregation. Special lenses for film interpretation, projection apparatus, and micro-densitometer measurements of X-ray absorption carry this branch of science into heretofore unsuspected realms.

Then too, so far as is humanly possible, samples of aircraft materials are subjected by other machines to all the fatigue, stresses, strains, and teriffic tensions existing in a plane hurtling through space at nearly the velocity of sound. Salt spray apparatus tests to the utmost the ability of plated and anodized parts to withstand the corroding rigors of wind and rain. Chemists, with sensitive electrometric devices, search structural alloys for impurities, the presence of which may mean the loss of air battles and lives.

While this steady routine goes forward day by day, other workers busy themselves with the unusual: New welding techniques, new heat treatment methods, new applications for new alloys, new uses for X-rays. Perhaps no one of these contributions is great in itself, but when added to similar work taking place in some of the other foremost American research laboratories, the total stands as a formidable retort to those who would belittle the vigor and power of our national defense preparations.

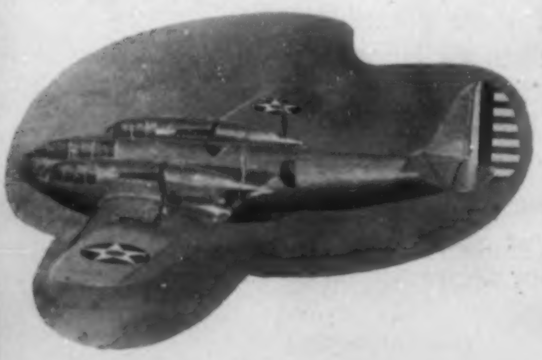
Some of the features of this laboratory and some of the products of the company are presented on this and the following pages.

General view of the chemical, physical, and X-ray laboratory.



A 200,000 volt X-ray laboratory with portable generating apparatus and completely lead-lined exposure room. There are 307 castings a day inspected here in addition to a large variety of other industrial X-ray examination and research work.

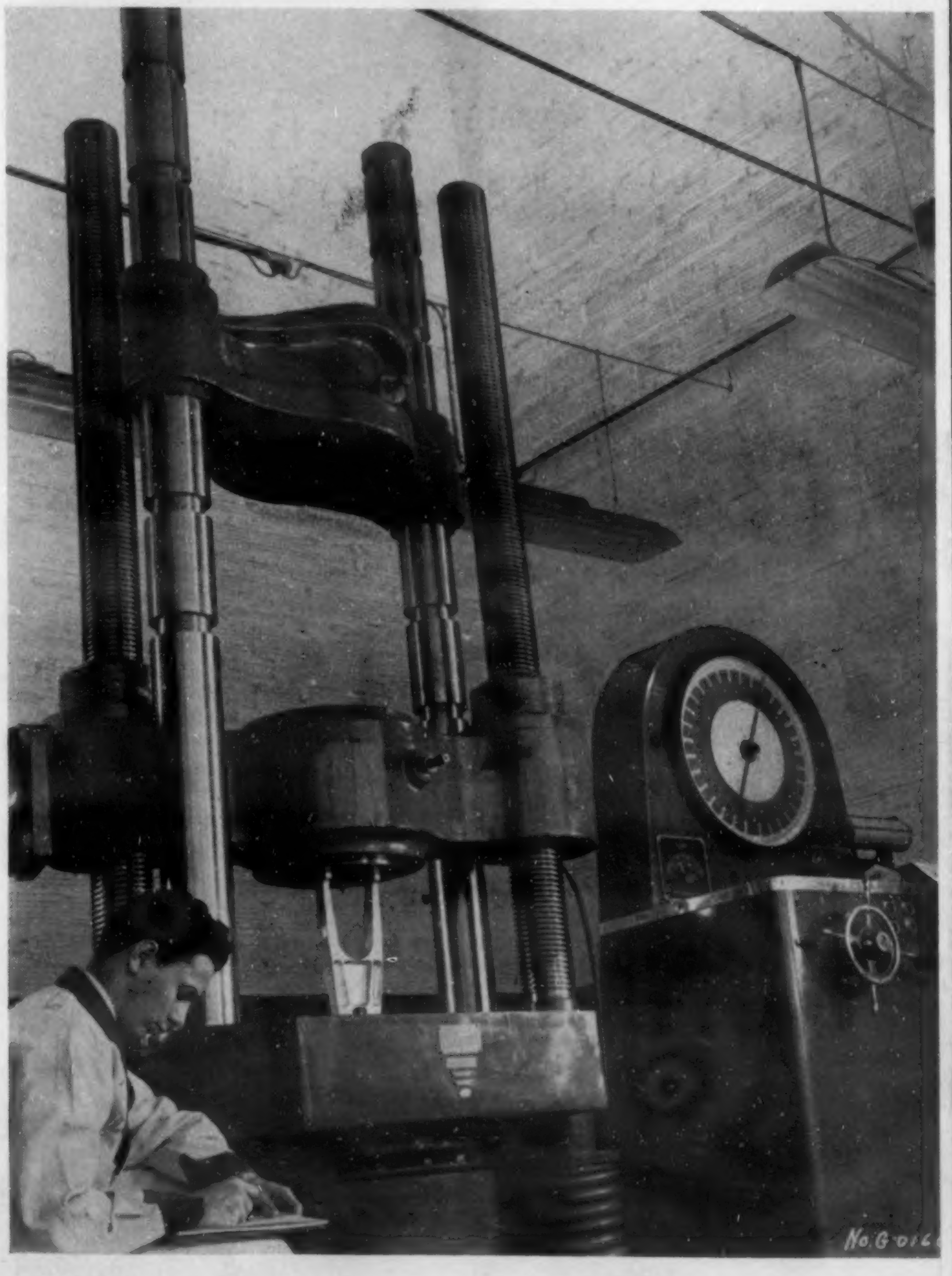
A Bell Airacuda multi-engine fighting plane. Rear protection—4 flexibly mounted machine guns.



A Bell Airacobra pursuit plane. Only single engine fighting plane made with motor amidships. Also only pursuit ship to carry a 37 mm. cannon and 4 machine guns. Speed about 400 m.p.h.

Metal failure due to fatigue is one of the major problems in the manufacture of airplanes. Reflex vibration fatigue tester with automatic recorder and, in background, Moore high speed tester which permits stress reversals on test bar over a million times each hour.

A sensitive potentiometric instrument for accurate determination of metal traces in solution. Apparatus may also be used as a portable pH meter.



A 300,000-lb. tensile-compression testing machine with Emery weighing system and extensometer unit for making accurate stress-strain curves. Brinell attachment and special microscopic equipment permit hardness determinations.

This 220-ft.-lb. impact testing machine will make Izod, Charpy, or tension impact tests with high degree of accuracy.

Testing resistance to corrosion of plated and anodized aircraft parts in the latest type of salt spray equipment. Such tests are particularly valuable on planes which will be exposed to sea air and moisture.

Bearing Metals from the Point of View of Strategic Materials—II

A Review

The second installment of this discussion, continuing the one published in September, deals in the latter part with certain phases of the strategic metal situation—tin and antimony—as they affect not only bearings and bushings, but also battery plates. The silver and gold situation is also discussed as related to bearings.—The Editors.

In the previous section it was shown that the behavior of a bearing is affected by many factors of design, dimensions and finish that have nothing to do with materials of shaft and bearing, and that when full fluid lubrication is established (and not interfered with by grit in the oil) behavior is not affected by the materials.

These statements need to be modified in that the initial finish which it is commercially feasible to give the shaft and bearing will vary with the materials, as does the way they wear-in in service; that shaft and bearing deflections, i.e., stiffness, are controlled both by design and materials; that materials that show plastic flow under the temperatures and pressures of service will not maintain the initial dimensions; that the important matter of operating temperature of a bearing, especially of the working surface of the bearing, is partly controlled by the thermal conductivity of the materials, and that the operating clearance may be affected by the thermal expansion of the materials.

It was shown that the primary need for proper choice of materials for shaft and bearing arises, not during the normal operation of the bearing, but during starting and stopping, when $\frac{ZN}{P}$ is too low to establish a complete lubricating film. This, too, needs to be modified in that the presence of grit in oil may occur in "normal" operation, that vibration may occur in service, as is discussed by Soderberg,[15] and that shaft and bearing deflections in service may likewise occur. However, all these factors are akin, in their effects on the supporting pancake of oil, to those occurring in starting and stopping, though their effects are usually more local. Such factors are the cause of the statement of Sparrow,[16] who says that the automotive engineer is a pessimist, he designs his bearings to maintain an oil film, but knows he will not succeed.

Galling, Seizing, and Scoring

In the breaking-in or wearing-in of a new bearing, the behavior is, as Figs. 7 and 8 in the previous installment show, an exaggerated case of what tends to happen during normal starting and stopping. The actual shaft and bearing are far from the perfectly smooth, perfectly true, perfectly cylindrical and perfectly aligned pair of surfaces envisaged by theory. If sufficiently magnified, the surfaces are a pair of corrugated wash boards full of peaks and valleys, out of round, conical and not in perfect alignment. Moreover, the surfaces are warped through deflection of shaft and bearing under load. The theoretical clearance calculated from the measured dimensions of shaft and bearing may be greatly exceeded or diminished locally at the actual mating areas. Due to end play, the mating areas will move back and forth over each other. Hence, no matter how carefully the shaft and bearing are prepared, they will

by H. W. Gillett, H. W. Russell and R. W. Dayton

Battelle Memorial Institute

fall short of mathematical exactness. Hand scraping of bearings, when hand work was the rule, was used to get a better approach to exactness and leave less for the bearing itself to do in the running-in period.

Any tall projections that, in spite of the oil film, actually hit each other and interlock, are naturally torn off or battered down very early in the wearing-in process, leaving only rounded peaks of large radius of curvature. Much of the smoothing process in wearing-in occurs as a sort of lapping from grit particles in the oil, or from metal particles previously torn off. Any such particle too large to pass through the clearance of the wedge of oil at the nearest approach of shaft to bearing tends to scrub the mating surfaces and rub off the films that are upon them. Similarly, as the shaft starts to move from rest, or comes to rest from motion, the opposing rounded peaks can touch and rub off the films. If the films are removed so that truly clean metal surfaces meet, even at the most minute points, they tend to weld together, nor need the temperature and pressure be high to promote this incipient welding.

When such welding takes place only in sufficiently minute spots, the motion of the shaft can tear the weld apart, a tiny chunk torn out from one member adheres to the other, later to be torn off or battered down. Welding followed by release, or the dragging along of a considerable volume beneath the weld before the chunk is torn loose, is called "wiping." This welding or galling, if on a sufficiently minute scale, may not roughen the surface seriously, and the wound may be healed by later lapping action. However, if it is on a sufficiently large scale, the shaft may seize, weld, or "freeze" to the bearing so firmly that it cannot be turned.

The lubricant is sometimes able to corrode or etch the metal surface, and such action may be selective upon some constituent of a non-homogeneous surface. Variations in seizure propensities, or in lappability of different constituents may also result in finally producing a worn-in metal surface with low hills and shallow pockets, rather than a mathematically perfect surface. Especially during the wearing-in period, the selection of a non-homogeneous alloy or intentional production of a slightly corrugated metal surface, so as to favor production of shallow hills and pockets may be helpful, in that the pockets may retain lubricant when the shaft is at rest, ready to spread by capillarity as soon as the shaft begins to move but before its motion makes it effective as a pump. The pockets may also be so placed that grit can dodge into them without doing much damage. Hence, too close an approach to a superlatively smooth finish, but one that still needs some wearing-in, may not be a good thing. Shaw[17] noted that a matte finish may give a lower coefficient of friction than a smoothly polished one.

Films

When a bearing has become thoroughly worn in, it has a characteristic glazed appearance, evidence that a film of some type has been built-up. This glaze may be analogous to "varnish" on pistons and rings, which is a troublesome cause for ring-sticking, and it may not have any virtue in itself, but merely be an evidence that, during the running-in period, the bearing surface behaved properly. Such a film might, of course, conceivably possess "E.P." properties and be a positive virtue, but we know of no direct evidence on this point. It would seem to be impossible to completely eliminate films from a metal surface in service. As electron diffraction shows, a truly metallic surface is a rarity and in any environment such as that surrounding a bearing, where many types of active materials are present, film formation would seem inevitable. Therefore, it is likely that the ordinary bearing is covered by a film during most of its life, and it is quite possible that such films are necessary to prevent seizing, since it is well known that really clean metal surfaces may weld together with the lightest rubbing contact.

The necessity for a film is very clear in the case of hypoid gears. Under the pressure and rubbing of steel against steel in these gears, seizure takes place in ordinary oils, and it is necessary to make "Extreme Pressure" additions to the lubricant, such as sulphur and lead soaps, which form a lead sulphide film upon the gears and re-form it as fast as it is scrubbed off. Under less severe conditions, in bearings, it suffices to add certain chlorides, phosphates, organic acids and the like, which tend to attack the surface and produce a film of adherent, tough corrosion product upon it. (But, in order to prevent too rapid corrosion by strong E.P. lubricants of the bushings used in gear boxes, the ordinary leaded bronze bushing may have to be replaced by alloys of the aluminum bronze type).

Under still milder conditions, the addition of "polar" molecules which are firmly absorbed by the metal surface, (or the retention in the oil of those naturally occurring there), will serve. Oxides and sulphides produced by the metals themselves with the atmosphere, the moisture and the sulphur compounds in the oil, enter into the films met on bearings and shafts. (Data from Campbell[18] show that the coefficient of static friction, determined in a particular manner, falls from 0.30 for clean metal to 0.15 with a sulphide or oxide film).

It is to be noted that "oiliness" additions have no effect whatever upon full fluid lubrication, their effect is solely exerted during boundary lubrication and seems to be due to an adsorption rather than to a true chemical reaction. It is fortunate that films are so readily formed, for if we really had truly

clean metal surfaces separated only by an oil film from which no layer was absorbed, seizure would make bearings impossible. From this point of view, a non-scoring or non-galling material is one that under the conditions of service, acquires and retains some sort of non-metallic film that hinders welding. The anti-seizing propensity of a bearing metal is an important feature in its suitability.

Embeddability

Grit in bearings is a serious cause of trouble; how serious depends on the type of bearing. In a rotating bearing, grit and particles of metal debris tend to be flushed out by the oil. In a reciprocating bearing, such particles tend to be trapped at the end of the stroke and ground back and forth between the moving parts. The service conditions in a reciprocating bearing are therefore the more severe, and may require different bearings or harder shafts. Grit is a source of difficulty because it may scratch through the protecting films and either directly abrade the metal, or clean it so that it will weld and gall.

This calls for another property of a bearing metal, ability to engulf or embed a grit particle and keep it out of contact with the shaft, a virtue that is called embeddability. If the layer of bearing metal, is too thin, as Swigert[19] points out, or if it only embeds without engulfing the grit, the grit so held may lap, or even score the shaft. Hence, against bearing metals too hard to engulf grit, it is necessary to use shafts so hard that they are not readily lapped or scored. If the hard shaft has a "non-metallic" surface, as when nitrided, or chromium plated and hence covered with a chromium oxide film, the shaft surface may be non-welding as well as non-scoring.

Underwood[20] suggests a way of providing a compromise between load-carrying ability on the one hand and embeddability and conformability on the other, in bearings in which the load is mostly on one half of the bearing. He cites a case of such a bearing in which the use of copper-lead for both halves caused scoring. The load was too high for the use of babbitt in both halves. But by making the highly loaded half of copper-lead and the lightly loaded half of babbitt, the bearing stood up without scoring, probably because of the embeddability for grit in the babbitt half. This scheme, he comments, may be applied to many bearings in Diesel engines and moderate speed bus and truck engines.

Embeddability is greatest in a material of low yield strength. A low yield strength may be valuable in another way. Underwood[21] says: "In trying materials other than babbitt trouble is sometimes experienced in unaccountable seizure to the shaft, and the trouble is laid to the lubricant and the lubricating system. The trouble is basically in the deflections of the crankshaft. Mere deflections, which are inherent in all engines to a greater or lesser extent and which are caused by flexibility of the crankshaft and crankcase, by lack of proper counter weights, by torsional vibrations, etc., produce local rupture of the oil film thereby actually allowing metal-to-metal rubbing. Babbitt or a similar non-scoring material is required to take care of this set of conditions. It will permit conforming of the bearing surface to fit the journal under the conditions of deflection without seizing or scoring." This is the property termed "conformability." Compare Fig. 6 in the previous installment of this discussion (September).

Conformability

In discussion of Underwood's paper, Dickinson remarked that a bearing metal should be elastic up to some particular pressure, with no permanent yield below, but above it the metal should flow to conform to local excess pressures. The yield strength should be low enough to prevent rupture of the oil film, so that the film may prevent metallic contact. The bearing metal must *not* yield at the maximum load of the bearing at the highest temperature at which it runs, but *must* yield and conform to high local pressures.

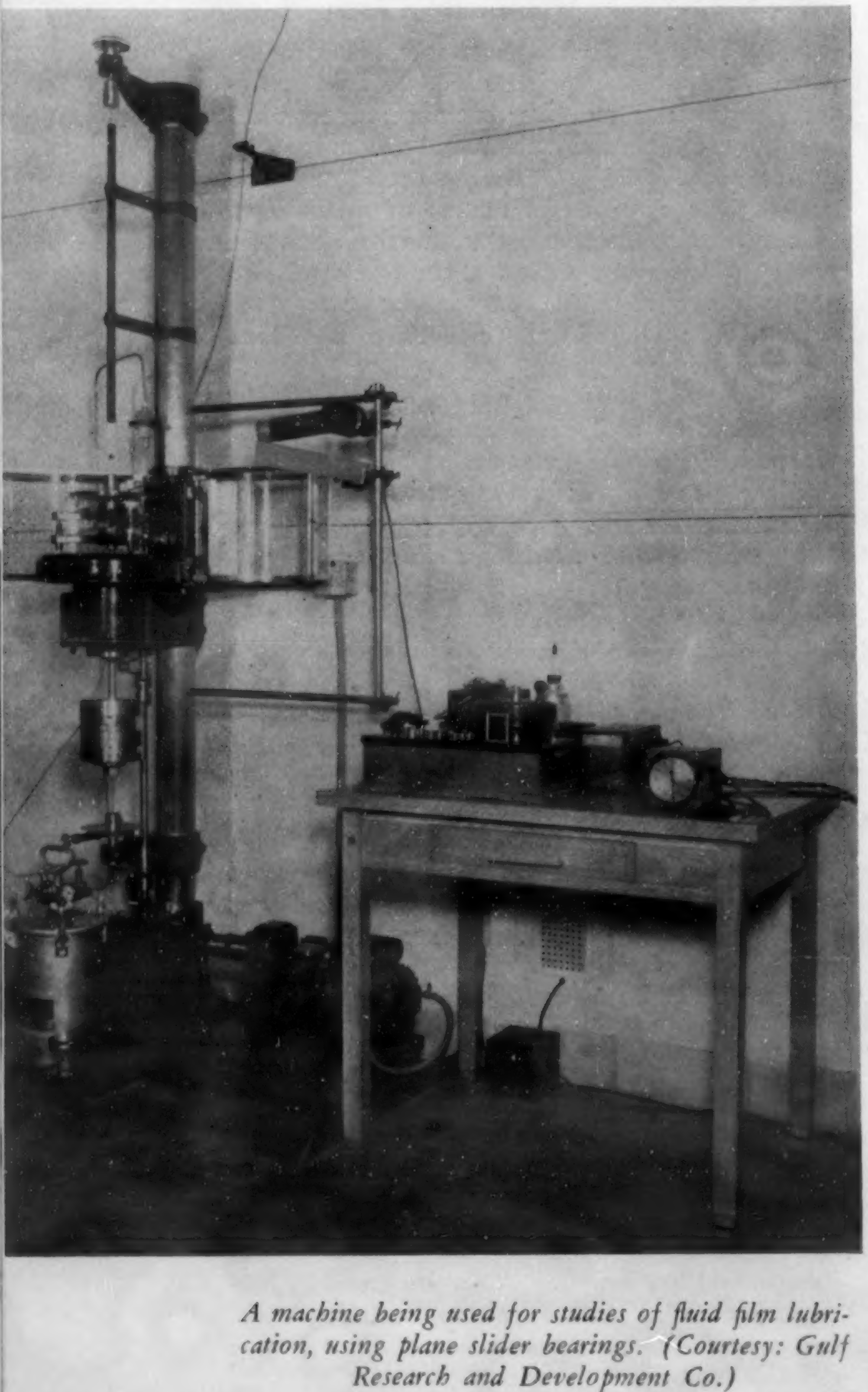
In the same discussion it was pointed out that the shaft deflection that causes the bell mouthing of the bearing resulting from the end pressure indicated in Fig. 6 in the previous installment, is not the same at different loads so that a conformable metal gets shoved back and forth like a piece of putty in order to conform to varying shaft deflections. It would be advantageous for the bearing metal to have a low modulus of elasticity so that it can easily accommodate itself and take up these changes in necessary contour, by elastic deformation. Actually, useful bearing metals do have rather low elastic moduli. Bassett[22] expressed this point of view and comments that low modulus can be provided by suitable choice of the backing material.

A low modulus or a low yield strength would serve to prevent the bearing metal from holding a piece of grit that is large in respect to the clearance, up against the shaft. Since such a piece of grit exerts high local pressure when it is caught in the clearance, the low modulus bearing can dodge out of the way more easily. This is analogous to the way a rubber wringer roll lets a button through and then returns to normal position.

The virtue of seizure resistance is partly ascribable to a specific behavior arising from the chemical composition, that of embeddability is ascribable to softness, and that of conformability to low yield strength and low modulus. They are found in babbitts compounded with low melting metals as bases, and vary with the amount and nature of the alloying elements used.

Bondability

Still another desired virtue in a facing for a lined bearing is bondability, the ability to form a firm bond with the bearing back. The liners of poorly bonded bearings obviously will be unable to stand as great loads as well bonded ones. Some authorities go further and state that cracking, the usual mechanical failure of lined bearings, is generally due to, or is only serious because of, poor bond and this cause of failure has not yet been proved entirely blameless. Willi[23] points out that as long as the pieces of babbitt adhere, the bearing may function nearly as well as though the lining were intact. However, it is obvious that if a crack runs from a location of high pressure to one of low pressure, it will have something the same deleterious effect on oil distribution as does a similarly poorly placed oil groove. Underwood[21] argues that oil pressure acting through a crack tends to undermine the lining and loosen the "tiles."



A machine being used for studies of fluid film lubrication, using plane slider bearings. (Courtesy: Gulf Research and Development Co.)

Fatigue Resistance

Other authorities ascribe the cracking of lined bearings to fatigue under repeated stress. Underwood[21], McCullough in the discussion of Underwood's paper and Macnaughtan[24] emphasize this for ordinary babbitts. Linings of 74 Cu-1 Ag-25 Pb are[25] evaluated as not sufficiently fatigue resistant for continuous service in aircraft engines. Silver is extremely fatigue resistant.

It is unfortunate that published data on fatigue resistance of bearing metals are very scarce, and not readily comparable. High ductility in a bearing metal is no insurance against fatigue failure, any more than it is in the fatigue of other metals, but there is a general belief that the harder, more brittle members of any series of babbitts are more liable to fatigue cracking than the softer ones. Nevertheless, as is generally true in fatigue, the stronger the alloy at operating temperature, the more likely it is, within limits, to resist fatigue.

Corrosion Resistance

A further necessity is that the bearing shall not be too severely corroded by the lubricant. At the temperatures at which they can operate safely from other points of view, the common tin base and lead base babbitts, and the bearing bronzes are not seriously corroded, but some oils rapidly attack some of the other bearing metals at temperatures at which we would like to use them. This is a matter of great importance in bearings for severe duty.

Complexity of Actual Bearings

As an engineering structure, a bearing is much more complex than merely two metals separated by a film of oil. Instead of three parts, it may have:

(1) The shaft body—giving stiffness and resistance to deformation, and affecting performance by its hardness, contour and surface finish.

(2) The shaft surface—carrying an oxide or other film in strong or weak chemical combination.

(3) The absorbed film of "oiliness constituents" of the lubricant, clinging to the oxide or other film on the shaft surface.

(4) The oil itself in the clearance space—containing dissolved air, moisture and oxidizable or oxidized constituents which may affect ultimate performance by corrosion, varnish

formation, change in viscosity, etc. The clearance dimensions are mechanically important.

(5) The grit and other foreign matter suspended in the oil.

(6) The absorbed film of "oiliness constitutents" upon the bearing, which may not be the same as that upon the shaft.

(7) The oxide or other film on the bearing metal.

(8) The bearing metal body with the effects of its hardness, contour, and surface finish, also of its thickness, if the bearing is a lined bearing (not a bushing).

(9) The bond between the lining and the backing, in a lined bearing.

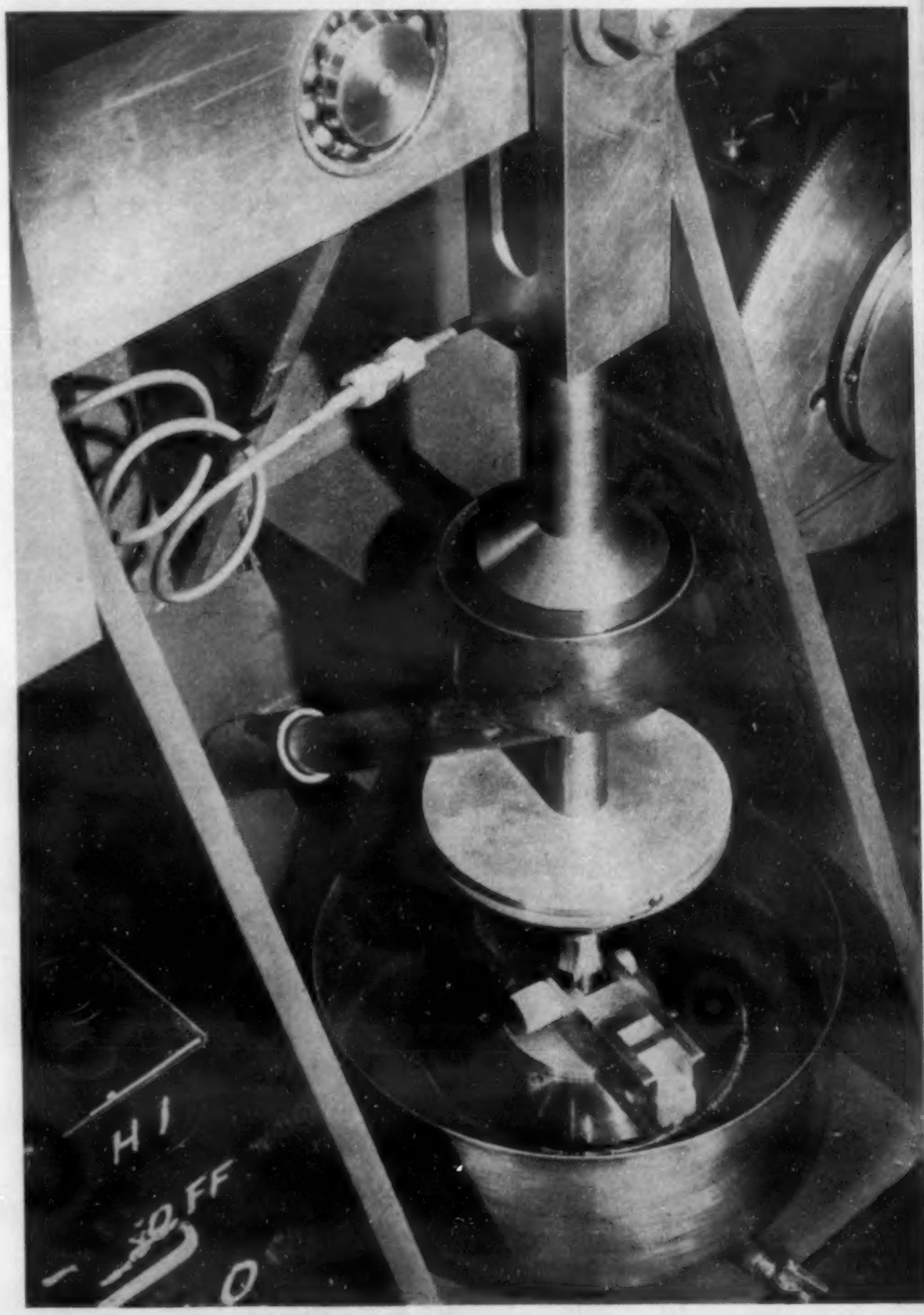
(10) The backing metal of the bearing. Whether the bearing is lined or a bushing, then come:

(11) The interface between the back and its support, the fit affecting the thermal conductivity and the flexure under load.

(12) The bearing support, having effects as to degree of stiffness and ability to drain heat from the whole bearing.

All these, plus the dimensions, the oil grooving or other means of oil supply, have to be chosen in respect to the load and speed, and the type of loading, whether unidirectional or reciprocating.

The other parts of the assembly, as well as the one bearing under consideration, affect the methods of oil supply, the oil temperature, and the ability to dissipate heat through shaft and bearing.



A detailed view of the test specimens of a machine being used to study departure from fluid film lubrication at high loads. (Courtesy: Battelle Memorial Institute)

Bases of Evaluation of Bearing Metals

A bearing metal needs to be evaluated on the bases of—

bondability (of a lining metal) and, whether it is a bushing or a lining, on—

resistance to pressure
conformability
embeddability
} load carrying ability, compressive yield strength, or creep, of which enough, but not too much, is wanted.

elastic modulus

resistance to fatigue

seizure resistance, behavior as a lap ability to adsorb "oiliness" constitutents } anti-friction characteristics

thermal expansion and clearance required

thermal conductivity

resistance to corrosion

It will be noted that no requirement is laid down as to metallographic structure. The old idea that a "bearing metal" must have hard particles in a soft matrix, as in ordinary babbitts, or soft particles in a hard matrix has been thoroughly exploded. The efficacy of tin, lead, or cadmium coating on pistons to carry them safely through the break-in period indicates that some pure metals have bearing properties, though here the analogy with sleeve bearings may not be exact.

Goodman[26] reported that, within its ability to withstand deformation, pure lead is an excellent bearing metal.

Boegehold[27] showed that a very thin film of pure tin on a supporting steel back functioned excellently as a bearing, and Underwood[21] says that pure lead, tin, cadmium, silver, and bismuth have excellent to good friction characteristics in somewhat the order listed. Several other workers have corroborated this for tin, and the commercial use of silver in aircraft bearings adds further evidence that a heterogeneous structure is not essential.

No discussion has been given above of "low coefficient of running friction" or "long wearing properties," though these are what we want in the operation of a bearing, and their determination has had much attention in the development of bearing testing. As was brought out in Part I, running friction is a resultant of bearing fit and finish, oil viscosity and operating temperature, and is affected by the way the bearing responds to wearing-in and to

grit. The real question is not so much how low a coefficient the bearing will show under most favorable running conditions, as whether we dare to operate it at a close approach to so low a coefficient.

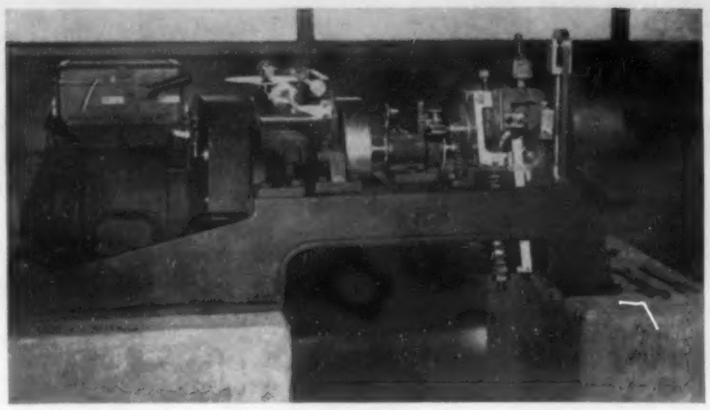
Wear resistance is a resultant of fit and finish, seizure propensities, behavior with grit, corrosion resistance (for formation of corrosion products that are wiped off shows up as wear) and strength and hardness. It is vastly affected by how the bearing is operated, as to temperature, nature of loading, and to cleanness of oil, and especially as to the relative number of stops and starts, i.e., the opportunity for seizure. It is extremely difficult to make wear tests in the laboratory or in service in which we can be sure that two bearing metals being compared are prepared and tested in truly comparable fashion. Long experience with large numbers of bearings of each composition gives a sort of over-all appraisal on the basis of increase in clearance but seldom tells just what specific property is producing the major effect.

Moreover, if a long-wearing bearing fails from poor fatigue resistance or as a result of poor bondability, it has no opportunity to demonstrate its property of wear resistance.

Any bearing metal is a compromise, no one bearing metal has all the virtues. Testing a metal to make sure it has the necessary virtues in proper degree without an improper degree of some of the drawbacks, is no easy matter. Hence the final test of a bearing metal is its behavior in actual bearing service. Specific tests can, however, often eliminate metals that would be useless as bearings.

The Factor of Temperature

All the properties need to be evaluated at the highest temperature it is desired to run the bearing, and, in a lined bearing, in respect to the actual thickness, on the actual back used, rather than in massive form. Temperature is a crucial matter. The properties of bearing metals at 300 deg. F. are decidedly more important than their properties at room temperature. Crank case temperatures on automobiles driven at 75 m.p.h. in summer may reach 280 deg. F.[28] The actual bearing surface temperature can be much higher. Nobody knows just how high the surface temperature of an airplane engine bearing may rise in a power dive. In general aircraft service, bearing temperatures are[20] at least above 275 deg. F. Williams[30] reports cracking of babbitt in 10 hrs. operation at 275 to 300 deg. F. Sparrow[16] says that bearing failures in automobile engines arise more from reduction in amount and viscosity of oil fed as a consequence of high temperature than from the effect of temperature on the bearing metals themselves, while McDonald[31] points out that bearing failures in Diesels most commonly result from excessive temperature, not excessive pressure, and is especially concerned with corrosion brought about by high temperature. Faulkner[32] remarks in relation to special alloy bearings, that what appeared at first to be lubricating problems resolved themselves into problems of engine design and cooling.



The Amsler wear testing machine which with proper control can be used to determine the seizure characteristics of bracing metals. (Courtesy: Battelle Memorial Institute)

Some bearings are so highly loaded that, at operating temperatures, bearing metals that are excellent for lower load will not serve, they will squeeze out. Underwood[21] points out that an automobile engine connecting rod is bushed with tin bronze at the upper end to take the piston pin. The rubbing speed is low but the pressure very high. A material of high compressive strength is required. At the lower end, where there is room for a larger bearing area so the pressure can be kept down, but the rubbing speed is high, tin-base or lead-base babbitt serves. If the two were interchanged, i.e., if the small end piston pin bearing were made of babbitt, it would squash out under the load and if the big end bearing were bronze, it would seize under the high rubbing speed.

Bearing metals that have been used in actual service range from pure lead linings with a Brinell hardness of 3 to 4 at room temperature, up to alpha-delta bronze, 81 Cu-19 Sn, for bridge turntables, with a room temperature Brinell of around 125 or more. The lead has a (tensile) yield stress of some 350 lbs. per sq. in., the high tin bronze a (compressive) yield stress of some 24,000 lbs. per sq. in.

Commercial Materials for Bearings

Materials in commercial use for bearings are, in the order of their hardness at operating temperatures:

Babbitts

Lead base—90-75 Pb alloyed with Sb and Sn
Tin base—90-80 Sn alloyed with Sb and Cu
Alkali hardened lead—98-95 Pb alloyed with Ca, etc.
Cadmium base—95-99% Cd alloyed with Cu, Ag, or Ni

Bearing Metals

Copper lead—20-35% Pb, balance Cu, perhaps with Ni or Ag
Silver—Pure, or containing a little Pb
Leaded bronzes—1 to 10% Sn, 10-35% Pb, balance Cu
Bronzes—Cu-Sn-Zn alloys with up to 10% Pb

Bearing metals suggested but only in experimental or very minor use are:

Aluminum base Magnesium base Zinc base	all variously alloyed

The babbitts are relatively soft at operating temperature, 5-15 Brinell at 300 deg. F. and hence have conformability and embeddability. The bearing metals are harder, 20 to 120 Brinell at 300 deg. F., lack conformability and embeddability, and require harder shafts and greater precautions against failure of lubrication. Seizure resistance decreases from the top to the bottom of the list. The babbitts seize with difficulty, straight bronzes seize easily. The only strategic metals in the list are: tin and antimony. Those restricted by supply or price are: cadmium and silver. All the others are readily available from domestic sources.

THE TIN SITUATION

According to statistics of the U. S. Bureau of Mines, the tin content of finished manufactures in the United States for 1937 was, in gross tons, 90,000, of which 73,000 was primary and 17,000 was secondary tin. Babbitt took about 6,800 tons, of which 4,500 was primary, 2,300 secondary, while bronze took 6,500, of which 3,700 was primary, 2,800 secondary. Slightly smaller amounts, but in about the same ratios, were used in 1939. The U. S. mined 34 tons in 1939! Of this, 33 tons came from Alaska. There are no figures on how the bronze was divided among bearings and other bronze articles, but in view of the large use of bronze for corrosion resisting purposes it is obvious that bronze bearings do not require the lion's share.

The bronze most used for bushings are, in the order of importance:

80 Cu-10 Sn-10 Pb —
83 Cu- 7 Sn- 7 Pb-3 Zn
85 Cu- 5 Sn- 9 Pb-1 Zn

Those most used for backs, to be lined with babbitt, are, in their order of importance:

85 Cu- 5 Sn- 5 Pb-5 Zn
85 Cu- 5 Sn- 9 Pb-1 Zn
80 Cu-10 Sn-10 Pb —

The bearing backs for railway cars approximate:

73 Cu- 6 Sn-20 Pb-1 Zn

The bronze bearing situation could be taken care of for some time by more thorough utilization of scrap. Railroad bearing bronzes are already made by remelt of scrap bearings, with only minor amounts of new metals. The smaller bronze bushings likewise use chiefly scrap as raw material, which is melted in cupolas in which the zinc is nearly all volatilized while the copper and tin, with some of the lead are retained. By addition of lead in the ladle and of a minor amount of tin or reclaimed solder, the desired compositions are made up. Actually, that part of the tin content of bearing bronzes up to 5 or 6 per cent tin can be figured as coming wholly from scrap, only the balance having to be added. As long as more scrap can be gathered when its price pays for collection, there is a reserve which can be called upon in an emergency, and tin-containing scrap could be primarily allocated to bearings, since for corrosion-resistant applications various tin-less copper-base alloys would serve nicely.

It would be desirable to find other strengthening elements for the matrix of leaded bronzes which are compatible with large amounts of lead and with the tin in scrap.

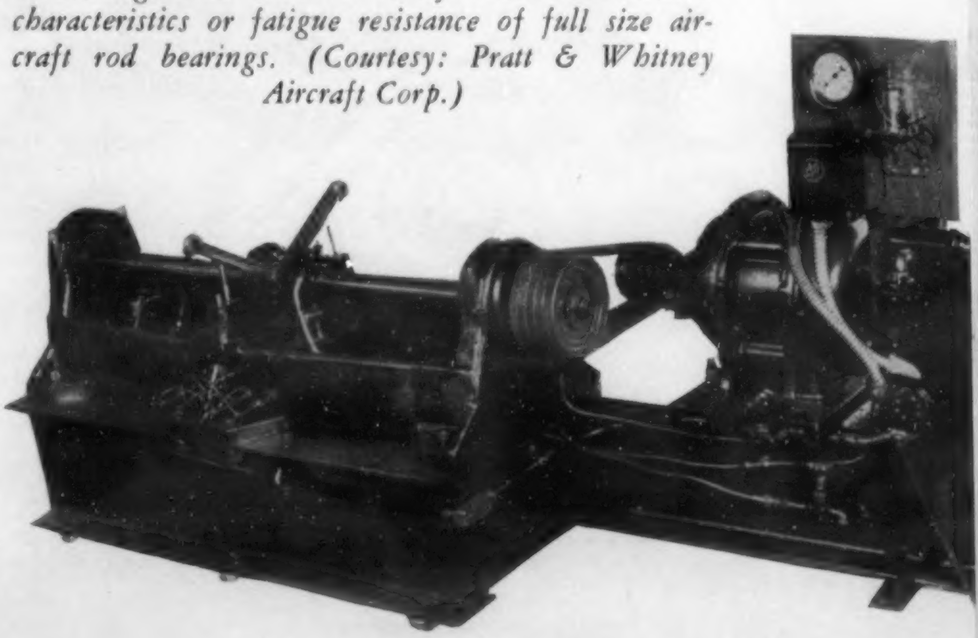
Bronze bushings are normally used with rather hard shafts, so that other materials that will run against hard shafts could be substituted with less difficulty than if soft shafts were used.

Hence it is the babbitt, rather than the bronze bearing, which needs chief attention from the point of view of strategic materials. A manufacturer of babbitt states that (outside of the automotive industry where most of the babbitt is tin-base), in the babbitt supplied for ordinary shop babbitting, perhaps 80 to 90 per cent of the total tonnage is lead-base, with 5 to 10 per cent tin, rather than the tin-base type very high in tin. Hence substitution for the small amount of tin in the lead-base alloys is almost as important as substitution for the tin-base type itself.

The Case of Antimony

The use of antimony as a hardening element in a tin- or lead-base babbitt might not appear to be in keeping with the status of antimony as a strategic

A bearing tester used to study either the seizure characteristics or fatigue resistance of full size aircraft rod bearings. (Courtesy: Pratt & Whitney Aircraft Corp.)



material, since China has been the chief producer. The world production in 1937 was in metric tons:

China	15,146
Mexico	10,638
Bolivia	4,230
U. S.	1,148

In 1937 the United States imported about 15,500 short tons, of which some 9,500 came from Mexico, only about 1,300 from China. The Japanese "incident" in China decreased the export of antimony so that in 1938 Bolivian production stepped to the top, above Mexico and China, although United States imports from Mexico were greater than from Bolivia. In all, 85 per cent of United States imports came from Mexico and South America. Mexican ore is now refined at Laredo, Texas.

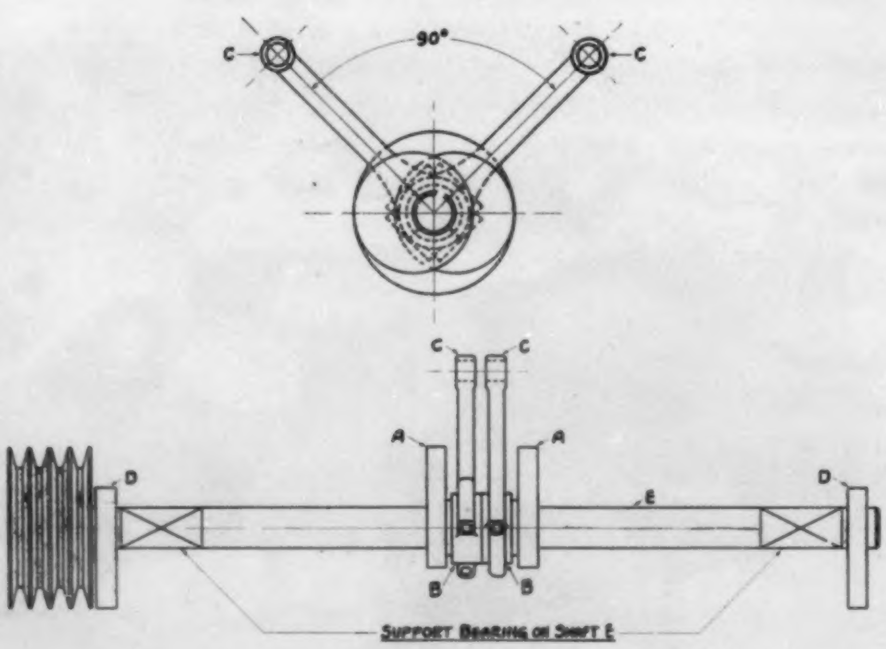
This hemisphere can supply a normal antimony demand, though actual United States production, actual or potential, is relatively small.

According to "Mineral Industry," 14,500,000 automobile storage batteries are made in an average year, each containing an average of 21.6 lb. lead plus antimony. (With the new headlights, the battery size and weight will increase.) If each battery contains 2 lb. of antimony, a year's stock of batteries contains 13,000 tons of that metal.

Calcium in Battery Plates

It would be possible to replace the antimonial lead battery plates by lead hardened with 0.1 per cent calcium (strontium will likewise serve). According to Haring and Thomas[34], whose opinion is backed by that of Schumacher and Phipps[35], the lead-calcium alloy is not only a substitute for, but in some ways superior to, the lead-antimony alloy. Calcium has been imported, but is now being produced in the United States and its production could be readily expanded, since there are plenty of raw materials.

The General Motors Bearing Tester, used largely to investigate the fatigue resistance of automotive rod bearings. (Courtesy: General Motors Research Laboratories)



Thus, through replacement by calcium, the antimony content of the storage batteries that go out of service each year could be called upon to supply antimony for use in babbitt. Lack of imports or disturbance at the Texas smelting plant could, therefore, be offset by using new lead alloyed with calcium for manufacture of new storage batteries instead of remelting old battery plates with the addition of a little new lead and antimony.

Cadmium base babbitts can, within certain limits to be discussed later, be substituted for tin-base babbitts. However, since cadmium is a by-product of zinc manufacture, the supply depends on the rate of zinc production and hence wholesale substitution of tin by cadmium is not feasible on the score of supply. The world's annual production of cadmium in 1937 and 1938 was 2,100 tons, of which the United States and Canada supplied 1,000 tons. Much of this is already used in bearings.

Silver and Gold

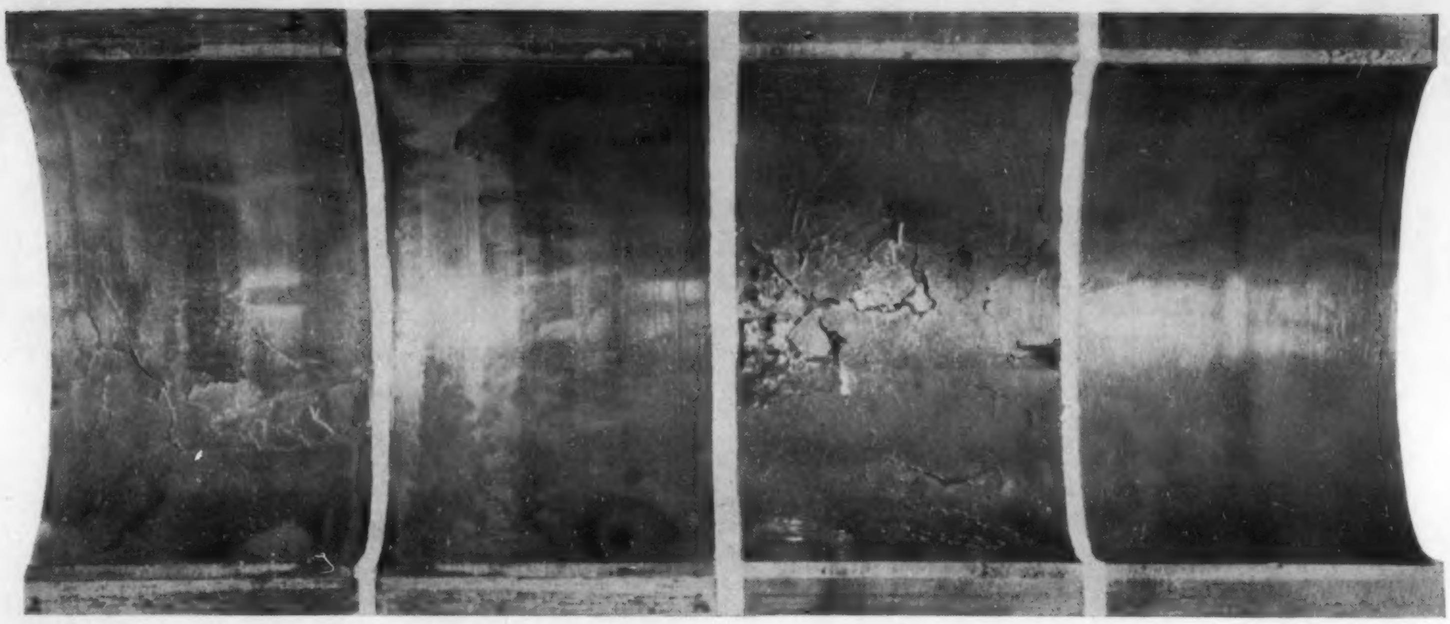
Silver is produced in the United States and in nearby Mexico and Canada. A large amount of silver is in storage for monetary purposes, with a further reserve in coins and in the sterling silver in the households of the country.

In 1939 the United States and Canada used 34,000,000 Troy ounces of silver for industrial purposes, while in that year the United States Treasury purchased 341,000,000 oz. In accumulated Treasury holdings at the West Point repository, at the Treasury, and in coinage, the United States government has some 2,930,000,000 oz. This is 100,000 avoir. tons.

If silver were substituted for the same thickness of babbitt, taking the difference in densities into account, there is enough silver in the possession of the government now to replace babbitt for 10 yrs., at the 1937 demand, and more silver is constantly being purchased.

The American silver producers have been actively engaged in trying to find industrial uses for silver. If silver is useful in bearings and if its use is justified either by normal economics, or by the economics of scarcity in a tin shortage, it will be used in bearings just as it is used in the movie industry and in amateur photography.

Indeed, if gold, which has a room-temperature Brinell hardness of around 30, quite in the range of materials of the super-babbitt type, were needed for bearings, there is enough gold to make a lot of bear-



A photograph of babbitt bearings which have failed in fatigue in the General Motors type of bearing tester. The rod halves of the bearings have cracked badly, the cap halves only slightly. (Courtesy: Battelle Memorial Institute)

ings. The gold supply in the United States accumulates so fast that statistics on it are always out of date—it is now over 20 billion dollars, figured at $35 per troy ounce. If the monetary needs in the past and the earmarked gold be subtracted, there is at least 12 billion dollars, or 340,000,000 troy oz., 11,000 avoir. tons, that could be released for industrial use. If a gold-plated bearing were good, that amount of gold would plate many bearings.

In the next installment we will consider the properties of the important bearing metals, from which the interchangeability of one alloy for another can be approximately determined.

(*To be continued*)

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Electrical Detection of Flaws in Metal

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Metal tubing, both ferrous and non-ferrous, is extensively used, particularly in any rearmament program. Applications include aircraft landing gear, engine mounts, fuselage frames, exhaust collector rings which resist corrosion, marine boiler and condenser tubes, and so on. It is essential to use as nearly a perfect product as possible.

The author describes a new method for the non-destructive testing of welded or seamless tubes, bars and other articles of both ferrous and non-ferrous metals, generally cylindrical in form. It is claimed applicable to non-magnetic as well as to magnetic material. A large American producer of tubing has been a user of the equipment for 3 or 4 yrs.—The Editors.

It is hard to overestimate the importance of metal tubing (or pipe) as an engineering material, because of its peculiar combination of properties, including maximum strength and rigidity with minimum weight, as well as the capacity to conduct fluids under pressure. As engineering and fabricating requirements become more exacting, the importance of freedom from mechanical defects and imperfections increases.

A few typical applications of tubing in the preparedness program include, aircraft landing gear, engine mounts, fuselage frames, exhaust collector rings (of corrosion resisting steel), marine boiler and condenser tubes, the oil industry, the chemical industry, parts of engines and their plumbing, etc. Demand for increased output for military purposes will be accompanied by more exacting technical requirements and the need for improved methods of inspection.

Tubing Made by Three Methods

There are three principal methods of producing tubing, including:

1. Forming from a flat strip and welding the seam by mechanical pressure, by acetylene or electric arc, or by electrical resistance.
2. Piercing a solid billet, followed by rolling.
3. Extrusion (of non-ferrous metals).

Size and wall thickness may be further reduced by cold drawing after any of the original methods.

The product of any of the methods is of course subject to mechanical defects or flaws. It is generally assumed that seamless tubing is more nearly perfect than welded, but this is not necessarily so. The assumption has arisen from the fact that any method of welding may occasionally produce defective results. Since there has heretofore been no reliable and practical method for 100 per cent inspection of welded tubing or pipe, the welded product has been regarded with suspicion. The hydrostatic method of testing is limited to the detection of actual leaks, or welds which are so weak that they will break under the applied internal pressure. Unfortunately, welds frequently occur which are only partially defective and which do not leak and will not break under the test pressure, but which will give way either in service under sustained or repeated stress or will fail under fabricating and forming operations.

It is interesting to note that if and when the weld itself is completely sound, the welded tube when made by modern methods is ordinarily superior as a mechanical product to the seamless tube. There are several reasons for this. Strip can be rolled to relatively uniform thickness across its width and along its length, resulting in uniformity of wall thickness and concentricity in the tube. Mechanical defects in the material such as pipe and segregation, since they arise in the center of the ingot, are located in the middle thickness of the rolled strip and therefore are not exposed on either the inner or outer wall of the tube.

Seamless tube, either pierced or extruded, is difficult to make concentric and may contain on its inner surface defects arising from the ingot or the piercing operation. Hot rolling may introduce further defects. If, therefore, welded tubing can be tested throughout its length so as to detect and eliminate imperfections in the weld which might prove harmful, it may readily become a superior product to seamless tubing, besides being less costly and taking less time to produce.

Seamless tubing has the advantage of some circumferential hot working in the process of manufacture. It can be produced in combinations of size and wall thickness impracticable by welding. It is therefore not likely to be eliminated as an industrial product. But the defects in seamless tubing may and often do exceed those in well-made welded tubing, so that it is equally important to subject seamless tubing to the same rigorous non-destructive tests for the elimination of mechanical flaws.

External defects arising in the ingot or billet, such as cracks, laps, blow holes, inclusions, etc., are supposed to be removed in the early stages of manufacture of either seamless or welded tubing. But inspection for such flaws is ordinarily visual and they too frequently miss detection and pass into the final product as elongated flaws or seams, where they are difficult to discover by ordinary means of inspection. The method of non-destructive testing described herein is equally applicable to welded and seamless tubing, regardless of the method of production.

Non-Destructive Testing

Burrows, a pioneer in non-destructive testing, advanced the theory that for every set of mechanical characteristics there is a corresponding set and only one set of magnetic characteristics. He proposed and initiated a system of testing whereby the measurement of magnetic characteristics yielded or was intended to yield desired information as to the mechanical properties of steel parts. This led naturally into efforts for the location of flaws or discontinuities in the material.

The principle has resulted in important contributions to the art of non-destructive testing and has had considerable practical application. It is unfortunately subject to certain serious limitations, since it is not applicable to non-magnetic metals, and when applied to steel or other magnetic material, harmless variations in mechanical properties often create larger variations in magnetic indications than are caused by serious defects. This latter peculiarity has caused untold difficulties in the work of magnetic testing for mechanical properties and flaws. The method will reveal flaws of considerable size and will distinguish between certain variations in the heat treatment or composition of steel.

With the purpose of developing a non-destructive test for metallic materials, especially tubing, which would detect mechanical flaws with a high degree of sensitivity, applicable as well to non-magnetic as to magnetic material, and eliminating in so far as possible the human element in testing, attention was given by the author and his associates to the use of electrical instead of magnetic methods.

The advantages of electric current over magnetic flux are pronounced. A mechanical discontinuity such as an open seam opposes over its area practically infinite resistance to the tranverse flow of electric current (provided of course that the voltage is not sufficient to cause an arc). If the surfaces of the seam are in contact, as may occur if imperfectly welded surfaces have been squeezed together in drawing through a die, then some flow of electric current will occur, but such opposed surfaces, even if clean, present an electrical resistance much greater than an equal path of solid metal.

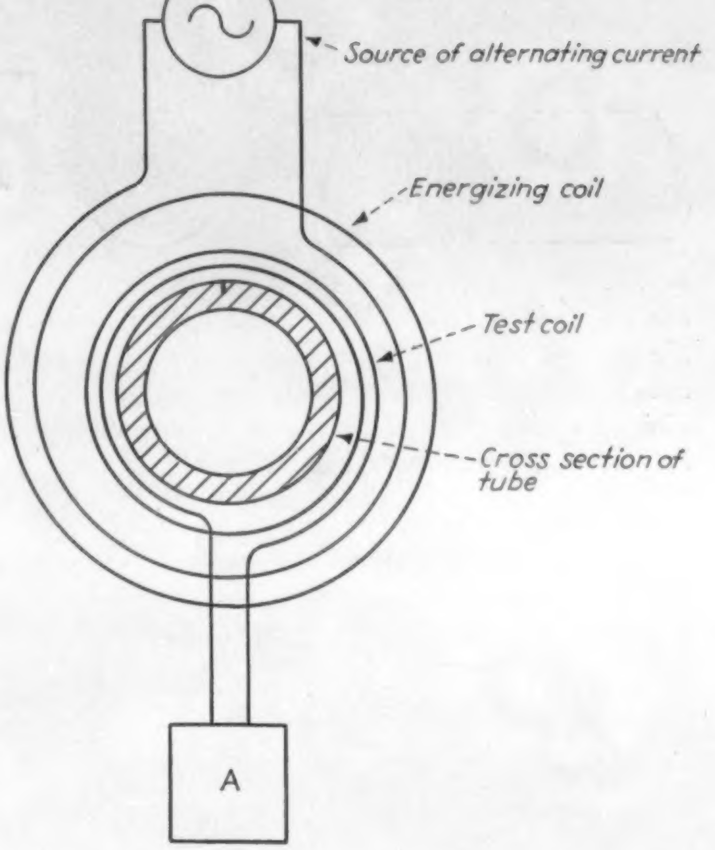


Fig. 1a. Simplified diagram. Alternating current, induced circumferentially in tube, is intercepted by a longitudinal flaw. Changes in this induced current are measurable by means of test coil and electrical indicator A.

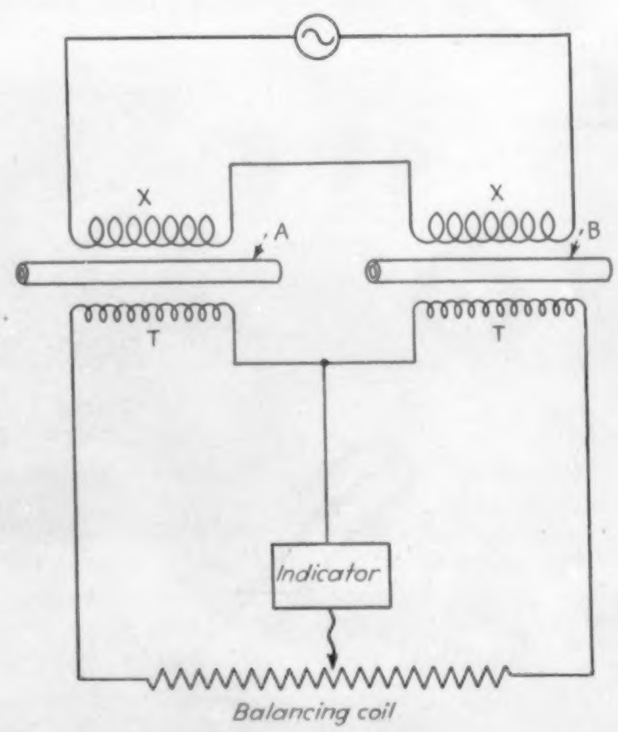


Fig. 1b. Simplified diagram. Two tube lengths, A and B, are perfect, the others under test, respectively, are surrounded by energizing coils, XX, carrying the same alternating current. Test coils, TT, also surround the tubes and are in balanced relation when no defect is present. The presence of a flaw in the tube under test upsets the balance of the test circuit and is measurable in the indicating device.

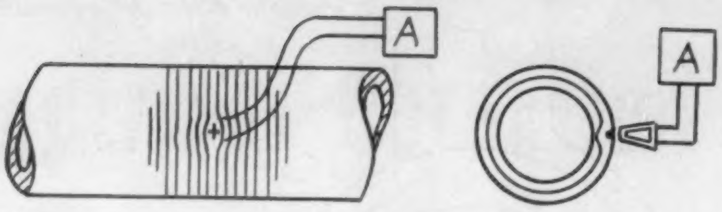


Fig. 2. A short or shallow flaw has little effect upon the total circumferential resistance of the tube, but the current is deflected around it, leaving a small, comparatively currentless area in the immediate vicinity of the flaw. This causes a large change in the reaction of a small conductor placed near the tube wall, tangentially to it.

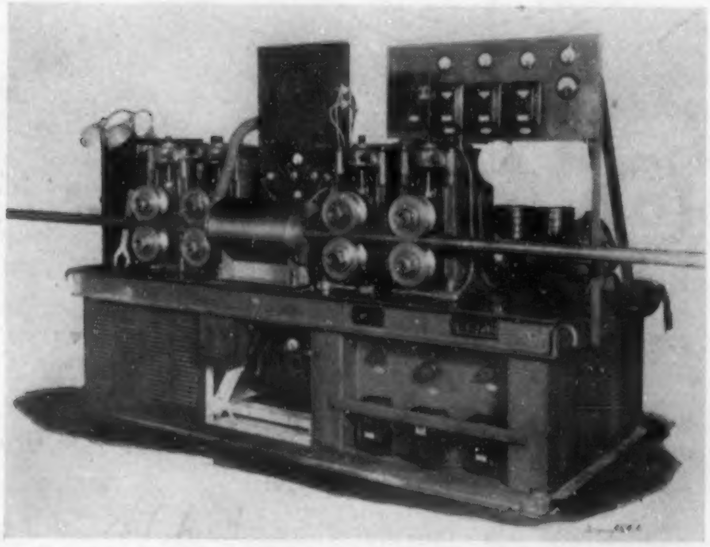


Fig. 3. Non-destructive electrical tester for production inspection in tube mill with power feed rolls.

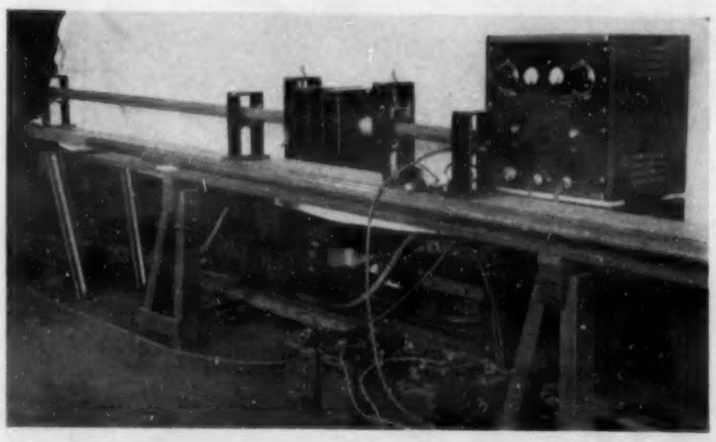


Fig. 4a. Experimental tester of simplified form, showing electronic and indicating equipment in cabinet, storage batteries for magnetic saturation, test coil assembly, and guide rolls.

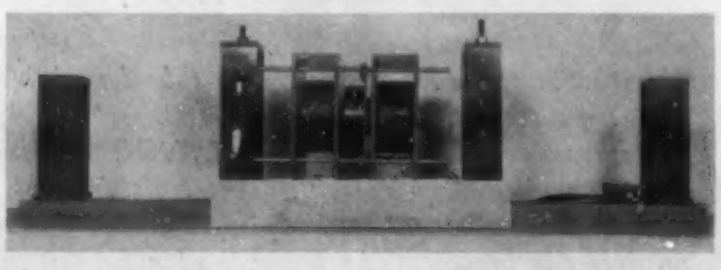


Fig. 4b. Closeup of coil assembly and hand-operated feed rolls of simplified tester of Fig. 4a.

Magnetic flux is not so greatly impeded by passage across such opposed surfaces. The reluctance is roughly proportional to the length of the air gap. The lines of force will travel through the air path more or less readily. Some leakage of magnetic flux will occur around the obstruction, which phenomenon is taken advantage of by the method developed by deForest, known under the trade name of "magnaflux." This latter method is limited to visual observation of the collection of magnetic powder upon the surface near the flaw. It does not operate instruments nor provide a permanent record unless photographed.

The problem therefore is to cause a flow of electrical current under controlled conditions, transversely to the direction of a possible flaw, and to measure the effect of a flaw on such current. This may be done in any of several ways. One method is to pass the tube through a set of energizing coils carrying alternating current, thereby inducing circumferential currents in the tube wall. Since the direction of flaws (whether from defective welds or other causes) in tubing is nearly always longitudinal, these flaws will be interposed across the path of the induced current.

By measuring the reaction of the latter upon test coils surrounding the tube, a measure of the effects of the flaw upon the induced current can be obtained, which in turn indicates the size and location of the flaw. These reactions readily may be caused to operate electrical indicating and recording instruments. It is another step to provide means for marking the tube at a flaw location, stopping its passage through the detector, or actually cutting out the flawed section mechanically, automatically.

Instead of relying upon magnetic variations in the tube, with their accompanying uncertainties, for the detection of flaws, these, in magnetic material are actually *suppressed* by the expedient of substantially saturating the piece with magnetic flux by means of direct current windings or direct current superimposed upon the alternating current windings. This saturation renders the steel substantially *non-magnetic* with respect to the alternating current used in testing. This device has resulted in virtually eliminating those variables which have given so much trouble heretofore in the testing of ferrous material by non-destructive methods.

There is another important point in connection with this saturating flux. Magnetic forces tend to cause the induced currents in a steel cylinder to remain near the surface or outer circumference of the body. This is called "skin effect." But when the steel, by saturation, is rendered relatively non-magnetic, the skin effect is correspondingly reduced. This results in increased sensitivity to the presence of deep seated flaws.

The principle of electrical non-destructive testing

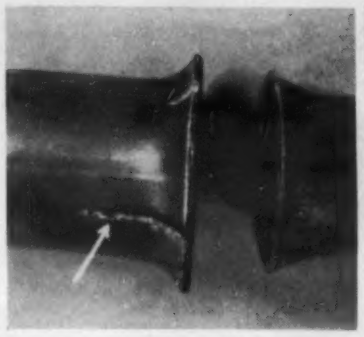
may be applied in a variety of ways. Some of these will be described. If two metallic tubes, identical except that one contains a flaw, are each surrounded by a similar electrical winding or test coil, then the reaction of the coils upon the alternating current flowing in each of them will differ as a result of the flaw. (Figs. 1a and b) For example, if an alternating current is passed through a conductor surrounding a tube, alternating current will be induced circumferentially in the wall of the tube. A substantial flaw extending longitudinally will interpose resistance to the passage of this induced alternating current, which will therefore be less than if the flaw were not present, or the phase relation may be changed. This difference can be measured externally electrically. By the elimination of the disturbing effects due to magnetic variations in the material by the method already referred to, highly sensitive and accurate electrical measurements are possible. Minute variations may be amplified and accurately recorded by the aid of electronic equipment. It is not the purpose of the present article to describe the electrical circuits.

Three Classes of Defects in Tubing

Defects in tubing may be broadly divided into three classes, (1) open seams, (2) seams or longitudinal flaws extending only partway through the tube wall, but of considerable length, (3) short flaws, and openings of very short length sometimes referred to as "pinholes." For the sake of clarity it may be mentioned that longitudinal mechanical defects in seamless tubing, for lack of a better name, are ordinarily referred to as "seams." A long defect extending fully or partway through the wall of a tube of moderate diameter will have a sufficiently pronounced effect upon the circumferential resistance to be readily detected by the use of detector coils extending completely around the tube.

The Tangent Coil Method

The short flaw or pinhole presents a somewhat different problem. Here the circumferential current is in effect merely deflected around the flaw and the effect upon the circumferential resistance of an appreciable length of the tube is extremely small. A different method of detection has therefore been developed, known for convenience as the "tangent coil" method. This is based upon the principle that while the effect of a small flaw upon the total circumferential current is small, there is an area closely adjacent to the flaw from which the current is almost completely deflected by the flaw, so that in this small area the change in current is great. (Fig. 2.) By placing a conductor of short length in close inductive relation to the area immediately adjacent to the flaw, a relatively large change in inductive effect can be obtained in this small conductor.



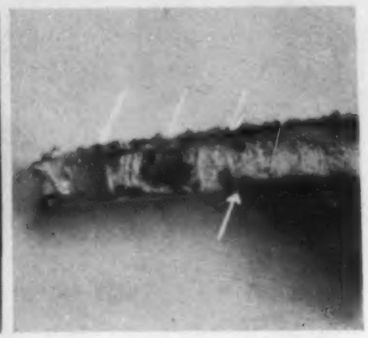
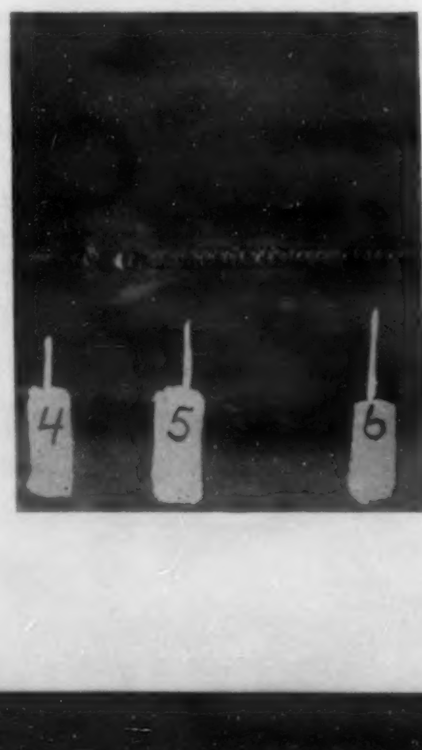


Fig. 5. (Left) Typical defect in electrical butt-welded tube, cut off and expanded at location indicated by tester, to reveal imperfect weld. Tube is $1\frac{1}{2}$ in. dia., 12 gage, low carbon steel. Same (right) weld broken open, showing short defects some of which penetrate only part way through the tube wall. Enlarged $2\frac{1}{2}$ times.

Fig. 6. Electrically-welded tube, $2\frac{1}{2}$ in. dia., 0.120 in. wall. Defect in weld 1 in. long, originally invisible but detected electrically. Expanded with plug to make it visible.

Fig. 7. Typical pinhole defect in a weld, visible on inside wall only after expanding tube with plug. Tube $2\frac{1}{2}$ in. dia., 0.120 wall.

Fig. 8. Acetylene welded stainless steel (18 and 8) tube, $2\frac{1}{2}$ in. dia., 0.049 in. wall, outer surface ground, making the weld and flaws invisible. View shows inside of tube, flattened at weld, detected flaws marked. Full size.



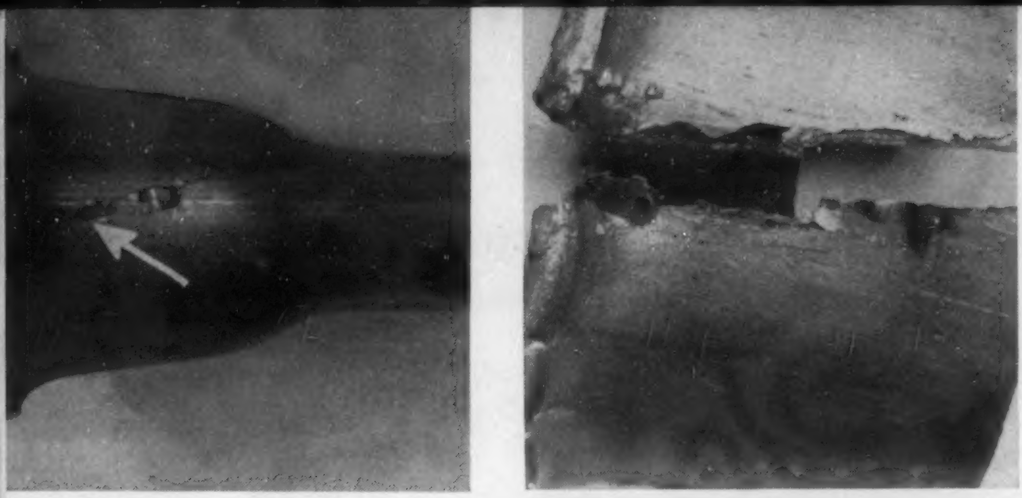


Fig. 9. Seamless tube, $1\frac{1}{4}$ in. dia., 16 gage. Tube cut (left) and expanded to open typical sliver type of external surface defect electrically detected. Same (right) enlarged $2\frac{1}{2}$ times.

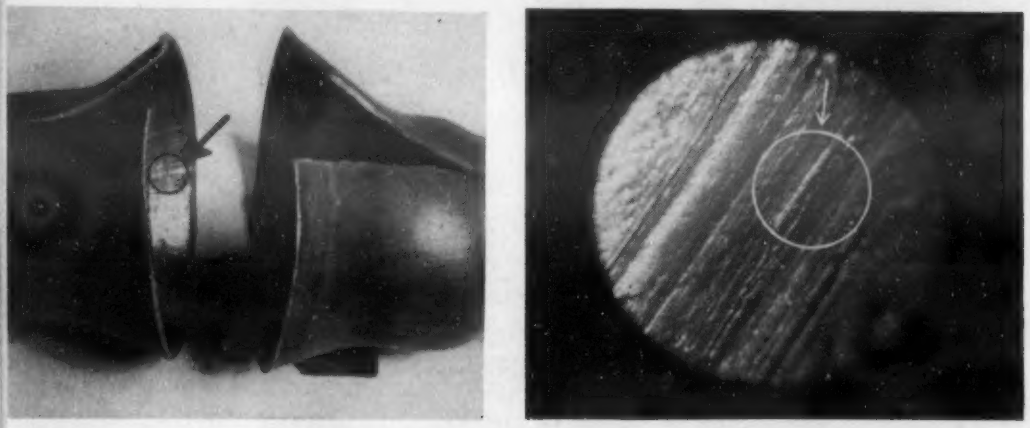


Fig. 10. Seamless tube, $1\frac{1}{2}$ in. dia., 16 gage. Tube (left) expanded with plug test, defect barely visible. Same (right) enlarged $8\frac{1}{4}$ times to show small seam on minor wall electrically located. Such a defect can start a fatigue failure.

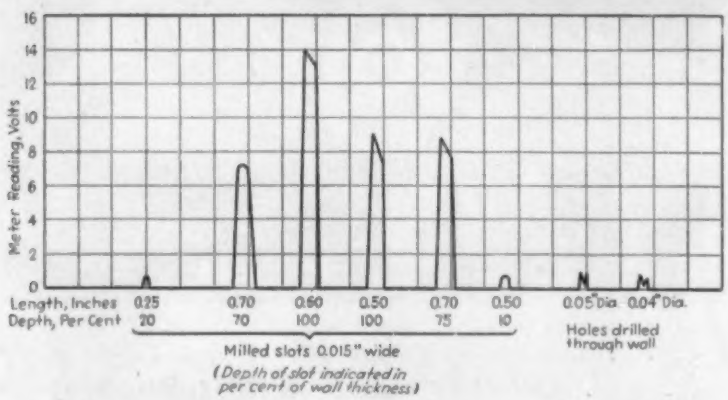


Fig. 11. Indications obtained on measured artificial flaws. Stainless steel (18 and 8) seamless tube, $2\frac{3}{4}$ in. o.d., 0.056 in. wall.

A coil or set of coils is therefore provided, shaped somewhat like the letter "D". That portion of the D coil which is closely adjacent and tangent to the tube wall is short, its length being comparable with the length of the short flaw to be detected with maximum sensitivity. The portions of the D coil which extend radially from the tube are in non-inductive relation thereto, and are fairly long. The connecting or outer segment of the D is far enough away from the tube to have relatively little inductive effect. This arrangement provides a highly sensitive reaction to changes of current in small areas of the tube wall. A series of such coils may surround the tube so that flaws in any part of the circumference are detected.

It is easier to detect differences in inductive effect upon two similar coils than to detect variations in one coil alone. These coils are therefore arranged in opposed pairs so that a flaw under one coil will not have an effect upon the other. If no flaws are under either, the inductive effect of the two coils will be in balance and no indication will be produced. Presence of a small flaw under one will destroy the balance and consequently give an indication.

It is interesting to note that this method avoids certain difficulties which are encountered with circumferential coils. For example, changes of temperature in the tube would change its resistance, but since the tangent coils are sensitive only to local variations, a change in the entire circumferential resistance of the tube will affect both coils equally, and therefore produce no indication. In tubes of large diameter, the relative effect upon the total circumferential resistance produced by a flaw is small, but since the tangent coils measure differences existing in two short circumferential arcs of the tube, the total diameter of the tube is unimportant.

Tangent coils, being adapted for high sensitivity to short flaws, are less sensitive to long flaws. Under certain conditions a combination of the two coil systems, circumferential and tangential, may be required.

Another modification of this electrical principle embodies the use of contactors. Circumferential current is caused to flow in the tube which is then passed longitudinally under two or more circumferentially spaced contact points. Differences in potential between such points are picked up and amplified by the detecting equipment. A flaw arising between any pair of points will therefore be readily detected. This method is subject to some complications due to difficulty of maintaining continuous perfect contact, the wear of contactors, electrothermic effects, and the like.

Commercial Application

The electrical method of flaw detection, in its various modifications, has been undergoing develop-

ment for a number of years and has resulted in a series of patents by the author and associates. The process has been in commercial use at the plant of Steel & Tubes, Inc., Cleveland, for 3 or 4 yrs., during which time it is estimated that more than 4,000,000 ft. of tubes have been successfully tested. The tester is operated on a 24-hr. schedule. Tubing is passed through it at the rate of approximately 50 ft. per minute. This machine, shown in Fig. 3, is capable of picking up flaws 1/8 in. long, extending half way through the wall of a tube of ordinary low carbon steel, having a diameter as small as 5/8 in., wall thickness of 0.040 in. The machine is arranged so that the presence of a defect will stop the feed rolls, whereupon the defective tube is removed, the flaw marked and cut out.

The same machine with modified set of test coils is capable of testing tubes up to 2½ in. in dia. Other testers have been designed for diameters up to 4 or 5 in. For the highly sensitive testing of large lots of small tube at high speed, a machine of considerable size and complexity is necessary. Many applications exist where this high sensitivity and high productive efficiency are not necessary. For such applications machines of much greater simplicity and less cost are adequate. These may require merely the energizing, detecting, and saturating coils, a pair of rolls for passing the tube through by hand and the necessary electronic equipment, together with a source of alternating current and a series of storage batteries for purposes of magnetic saturation. (See Figs. 4a and b.) Depending upon the degree of sensitivity and the other determining circumstances, the tester may vary widely in construction and design.

Hydrostatic and Electrical Methods Compared

A comparison between the hydrostatic method of test and the electrical method is interesting. Two men are required for the hydrostatic test, but only one for the electrical, and the latter is faster. The electrical method will record and mechanically reject defective material, while the hydrostatic depends on personal observation. The hydrostatic test reveals only such defects as will show leaks or burst at the testing pressure applied.

Partial welds, or those in which a portion of the thickness of the tube wall is defectively welded, will frequently withstand a hydrostatic test without rupture or sign of leakage. Such defects may later open in service or fail in forming, bending, or other fabricating operations. The electrical test will detect such partial welds, and will at the same time detect those defects (leakers) which are found by the hydrostatic method. Adjustments make it possible to set a given tester to pass flaws smaller than a selected size, so that unnecessary rejection is avoided.

Typical Applications

The apparatus is suitable for testing any type of metallic tubing including plain carbon and alloy steels, stainless steel of the non-magnetic or austenitic type, brass, copper, aluminum alloy, nickel and its alloys, etc. Typical applications include tube for aircraft, axles, boilers, condensers, Diesel engines, drive shafts, electronic tubes, radiators, refrigerators.

Certain characteristics of the tester must of course be varied according to the composition of the material and the size and wall thickness of the tube. The method is applicable not only to tubing but to bar stock and cylindrical forms, being particularly sensitive to flaws near the surface. It may be modified for other forms of conductors, such for example as cylinders, rings, bearing races, etc. The accompanying illustrations of flaws detected by this method are of particular interest, selected from a great variety of samples. (Figs. 5-10.)

The application of 100 per cent non-destructive testing to tubular materials opens a wide field for the application of both welded and seamless tubing under more rigid engineering requirements. It also affords great opportunity for economy through the rejection of defective material in the early stages of manufacture, thus eliminating processing costs on work which would prove defective in final inspection or in service.

The writer, who received his early college training as an electrical engineer before entering the metallurgical field, is responsible for the more primary conceptions of the various processes, and is indebted to his former assistant, Mr. Cecil Farrow, now connected with Steel & Tubes, and his associate, Mr. A. R. Sharples, electrical engineer, for solution of the highly technical problems involved in some of the circuits and the electronic amplifying and controlling devices.

The development of the process was initiated and carried out on behalf of Steel & Tubes, Division of Republic Steel Corp. Most of the early work was done at the plant of the Metlab Co. (Metallurgical Laboratories, Inc.) of Philadelphia. The construction of commercial apparatus and further improvements in technique are in the hands of the Sperry Products, Inc., of Hoboken, N. J., well-known for the Sperry rail tester for detecting transverse fissures in railway rails, and more recently for the development of continuous butt welded rails.

The writer wishes to express his appreciation to Mr. Henry Wick, vice-president of Steel & Tubes, for his courage and vision in supporting this project through the difficult and often discouraging period of technical development.

A simplified form of the detector will be exhibited by the Sperry organization at the National Metal Exposition, Oct. 21 to 25, Cleveland.

(Editorials continued from page 403)

chromium by manganese and by molybdenum or other carbide formers in the general run of S.A.E. steels, mentioned by Taylor, are far better understood today than in 1929, and some advances have been made in practices for introducing chromium into steel that may facilitate the utilization of chromium from low-grade ores.

Considerable advance has been made in understanding of the feasibility of replacement of tin in tin plate for cans, in solder and in babbitt.

The manganese situation remains important in spite of expanded Cuban production. Yet the open-hearth man can, in a pinch, make much greater use of spiegel in place of ferro, and there is a large reserve of Cuyuna and other domestic ores suitable for spiegel. At the worst, and given time to erect the plants and get the bugs out of the process, electrolytic manganese, obtained by leaching low grade ores, may be in the picture, but that is a long and expensive way around, compared with the direct road through spiegel.

Taylor's comment that, after it has been determined that a certain substitution can be made, "its introduction will involve a changed technique whose introduction during an emergency may cause loss of valuable time," is still highly pertinent. There are generally hidden bugs in new processes, and even in what may appear to be straightforward substitutions, so that, in an emergency, one cannot rely too much on plausible paper calculations by starry-eyed enthusiasts or axe-grinding patentees for the benefits of brand-new schemes. Main reliance has to be placed on research previously carried on, and plant experience previously gained from the point of view of every-day, normal-condition, economic considerations—with molybdenum high speed steel as a shining example.

To carry through the period where the bugs are being chased down and eliminated, what Taylor called "reserve stocks" and what we generally speak of now as "stock piles," are essential. Necessity for them was clearly recognized by the Army, as Taylor's article shows, but it has taken a long time for the administration to get to the point of doing anything about what has so long been known and so clearly pointed out. A more realistic and business-like administration can be expected hereafter.

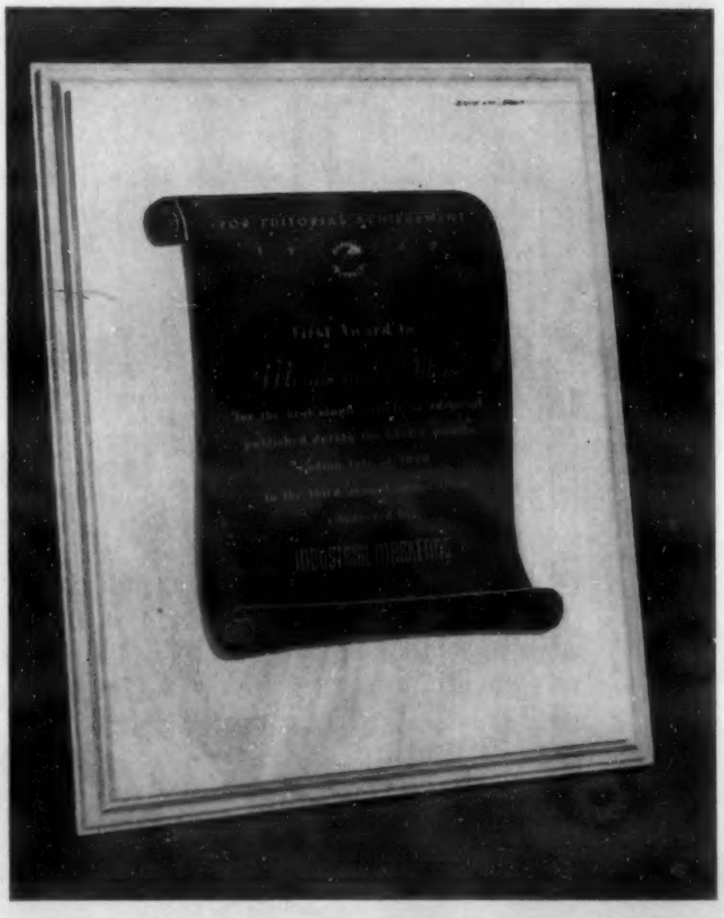
But nobody sitting in Washington can see all the possibilities and limitations in the possible saving in, or substitution for, strategic metals. Such savings and substitutions come as the sum total of very specific investigations and plant trials that have to be made by the metallurgical and metal-using industries themselves. Every such industry is fully alive to the strategic problem, and self interest as well as patriotism leads them to plan intensively for alternatives in possible shortages.

It is to past effort, to intensified present and continued future effort in these lines that we may turn with considerable assurance that not only are we in much better shape as to strategic metals in 1940 than in 1929, but that we shall be in still better shape in 1941 and thereafter.—H. W. G.

We Receive an Honor

An honor, which the editors of this magazine value very highly, has come to the staff and to the Reinhold Publishing Corp.

In the third annual competition, conducted each year by *Industrial Marketing,* the first prize was awarded to METALS AND ALLOYS for the best single article (or editorial) in technical and professional papers for the year ended July 31, 1940—"The Industrial Application of Austempering" by E. E. Legge, assistant director of research, American Steel & Wire Co., Cleveland, and published in August, 1939. The presentation of a beautifully engraved metal plaque was made to the editor on Sept. 19



at the annual convention of the National Industrial Advertisers Association in Detroit.

Those of us intimately associated with this work are justly very proud of this honor and recognize at the same time the value of the contest in bringing to the attention of advertisers and others the standards which editors are attempting to maintain—this is a spur to even better work. A year ago during the second annual reward, we received an Award of Merit for the best typographical improvement.

Powder Metallurgy

— Recent Advances and Design Trends

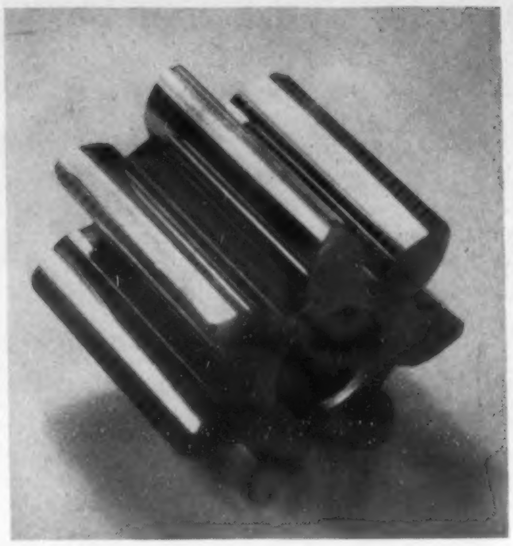


Fig. 1. Sintered oil pump gear made from iron powder—described by F. V. Lenel.

A REPORT OF THE M. I. T. SUMMER CONFERENCE

by FRED P. PETERS

Assistant Editor

Despite all the glittering generalities about powder metallurgy that have been written and uttered in the past, practically every one of the 110 busy men who attended the 1940 Summer Conference on Powder Metallurgy held at Mass. Inst. of Technology, August 29th, 30th and 31st came away with the conviction that powder metallurgy was passing out of its ballyhoo stage, that its literature will henceforth be more fact than fancy and, particularly, that —oversold or not—it is eventually to occupy a highly important place among the metallurgical engineering unit operations.

Most ably organized and directed by Professor John Wulff of M. I. T.'s department of metallurgy, the conference was notable in presenting among its 21 papers several that actually revealed specific and useful facts about processing or design not previously available. And also, because the roster of those participating and attending included practically all the dominant factors in the manufacture and application of powdered metals in this country, there was a far greater off-the-record exchange of valuable information on the subject than had ever occurred in one place before.

As P. E. Weingart of U. S. Metals Refining Co. said in handing over his gavel as chairman of the final session, "The lid is off! For the first time we've all gotten together, looked at our problems and accomplishments realistically and have seen the truly great potentialities in powder metallurgy, given intelligent handling all around."

An interpretation of the whole conference would simply be that these potentialities lie chiefly in the use of powder metallurgy practice *as a fabricating process* for many products at present made exclusively by casting-and-machining, by die casting, by casting-on, etc. This trend was reported by H. E. Hall of Metals Disintegrating Co. in his paper "Developments in Metal Powders and Products" and by E. S. Patch of Moraine Products Div., General Motors Corp., in his talk on "Industrial Limitations of Powder Metallurgy." Specific evidence of this "replacement" development was embodied in the paper by F. V. Lenel of Moraine on "Oil Pump Gears—an Example of Iron Powder Metallurgy," which gave a wealth of design and operating data on the production from powdered metals of an important product formerly made by casting-and-machining, and also in the papers by A. L. Boegehold of General Motors Corp. Research Laboratories Div. on "Copper-Nickel-Lead Bearings" and by G. M. Howe of General Electric Co. on "Development of Sintered Alnico."

Many specific data were also presented in several other excellent papers on various modern products of powder metallurgy, on methods and equipment, and on raw material powders—so many, in fact, that we can merely cite the high spots here and recommend study of the original papers when they are finally published.

The Present Field

In his paper, Hall presented an excellent general review of the whole field of powder metallurgy. Today this field is small on the basis of pounds or tons of metal powder used, but it is important out of all proportion to its physical volume. A relay contact made of a gram or two of powdered metal may be vital in the safe operation of an airport; the two tiny distributor points of today's car can be the difference between a smooth-purring mechanism or a cussable mass of inertia.

The powder-process often reveals an unsuspected versatility. Thus, in forming current-collector brushes, the use of *flake* copper powders gives a laminated structure, and if the molding pressure is applied at right angles to the direction of ultimate current flow, the electrical resistance of the brush will be lower in the current-flow direction. Molded combinations of metals and non-metals are becoming increasingly popular. Competing with non-metals, porous metallic filters are now being produced from metal powders to take the place of ceramic filters for handling caustic solutions and other chemicals.

Among the newer products of powder metallurgy are contacts of tungsten carbide bonded with 3 per cent osmium. The Carboloy Co. have recently marketed cemented carbide parts produced by *extruding* (instead of pressing) powders through dies and at pressures high enough to compact them. Metal powders may be applied (with a paint-type spray gun) to the surface of non-conducting materials to form the cathode for subsequent electroplating.

Hall discussed in some measure most of the products described in detail by other speakers, as did A. W. Deller in his "Patent Survey of Powder Metallurgy." Thus, tungsten, out of whose necessity were mothered the inventions that led to the general commercial development of powder metallurgy, was usefully discussed along with tantalum, molybdenum, etc. by H. W. Highriter of Fansteel Metallurgical Co. in a paper on "Refractory Metals." The cemented tungsten carbides were discussed in "Tool Compositions of Cemented Hard Carbide" by P. M. McKenna of McKenna Metals Co., with special emphasis on a new tungsten-titanium carbide (Kennametal), said to be particularly useful for machining steel.

Among the other products that cannot be made by melting are the tungsten-copper and allied electrical contacts. These were reviewed by F. R. Henzel of P. R. Mallory Co. in "Physical Properties of Metal Compositions with a Refractory Metal Base." A new age-hardening material of this type was described (composition could not be divulged) as having excellent contact characteristics and a tensile strength of 175,000 lbs. per sq. in., 110 Rockwell B hardness, 30 per cent I. A. C. S. electrical conductivity, and specific gravity of 14.5.

Much interesting information on the increasingly familiar self-lubricating porous bronze bearing was presented by R. P. Koehring of Moraine in his "Sintering Methods and Atmospheres for Production Purposes" (reviewed in later paragraphs). One of the highlights of the whole meeting concerned such bearings and was presented by Hall as a supplement to his paper—a *Kodachrome motion picture* showing the micro-structural changes that occur during the sintering of a copper-tin-graphite mixture. [This was a much-extended "movie" version of the colored micros of this same subject published by Mr. Hall in the October 1939 issue of this magazine.]

Powdered Metals in Main Bearings

A particularly striking example of the solution of an engineering and design problem by powder metallurgy after conventional practice and products had been less than satisfactory is the new General Motors Durex bearing for engine main bearing and connecting-rod bearing service. Described by A. L. BOEGEHOLD of General Motors Research Laboratories in "Copper-Nickel-Lead Bearings," the new product consists of a steel backing on the surface of which is sintered a 45 nickel, 55 copper powder sponge whose pores serve as an anchor for a lead-base bearing alloy (3 per cent tin and 3 antimony). The bearings can be finished to leave a 0.001 to 0.002 in. layer of lead alloy over the top of the copper-nickel sponge or—for heavier duty engines—the bearings may be finished by diamond boring, so that the copper-nickel sponge is exposed for load-carrying purposes at the bearing surface. The structure of such a bearing is shown in Fig. 2.

Generally speaking, this Durex bearing meets *all* the requirements of a good engine bearing—strength and fatigue resistance at operating temperatures, ability to form a strong bond to the steel back, enough conformability to permit flow at points of insufficient clearance, frictional characteristics to permit high shaft speeds and loads without galling or seizing, and resistance to corrosive attack by constituents or oxidation products of oils—something that neither tin-base babbitt, lead-base babbitt, cadmium alloy or copper-lead was able to do.

Fig. 2. Structure of Durex bearing surface. Matrix-babbitt interface material appears as a continuous band surrounding the copper-nickel matrix. Etched with ammonia persulphate plus ammonia; 500 X.

The method and equipment for mixing and applying the powders, compressing the matrix by passing the coated strip through chromium-plated embossing rolls at a pressure of 10,000 lbs. per sq. in. and for applying and anchoring the lead alloy by passing the sponge-coated steel strip through a "vacuum tunnel" in which the lead alloy is sucked into the sponge were described in an article by R. P. KOEHRING in the August 1940 issue of *Metal Progress*, page 173.

Oil Pump Gears

A direct comparison between the quality and cost of an automobile part—an oil pump gear—made by pressing and sintering on one hand, and casting and machining on the other, was provided by F. V. LENEL of Moraine in his paper "Oil Pump Gears, an Example of Iron Powder Metallurgy." During the 1940 car year the entire needs of one large automobile manufacturer for oil pump gears were made from molded iron powder. A sintered gear of this type is shown in Fig. 1.

The raw material so far used has been so-called Swedish sponge iron although [as pointed out in the article by A. T. FELLOWS in last month's issue] this raw material may soon have to be replaced. To be suitable for this purpose, an iron powder must be low in oxides and silica, because the latter rapidly wears the briquetting tools. Carbon content should be low enough to leave the powder soft. Physically, the powder particles should be relatively yielding so that they stick together when briquetted. The powders should be low in fines and have an apparent density higher than 2 gms. per cc.

In making the gears, the iron powder is mixed with graphite powder, which not only supplies the necessary carbon for alloying but acts as a lubricant in molding. Briquetting is done in automatic machines

at a pressure (40,000-60,000 lbs. per sq. in.) that represents a compromise between wear of the tool and strength of the piece, both of which increase with rising pressures. Die parts—die barrel, upper punch, stripping punch and pilot—are made of hardened tool steel, the die barrel wearing the fastest. A smooth surface finish on the die barrel not only improves its life but is essential to the surface finish of the gears.

The briquetted gears are sintered in a continuous electric furnace—a modified brazing furnace with a partially-burnt natural gas atmosphere. Sintering temperatures are as high as heating elements permit, since time should be kept short for reasons of economy as well as to reduce and control the amount of shrinkage. Shrinkage in iron parts is held to less than ½ per cent. On the other hand, increase in sintering time and temperature aid diffusion of the carbon and improve the mechanical properties. Again a compromise, sintering time is therefore 20-40 min. at about 2000° F.

The sintered gears as they emerge from the cooling zone are impregnated with oil and are almost ready for use. Tooth surfaces are not touched again after sintering; the four finishing operations actually employed are burnish-broaching the inside diameter, grinding the outside diameter, machining the end-length and chamfering the teeth, only a few thousandths of an inch being removed in each case.

Fig. 3. Microstructure of a sintered iron gear of approximately eutectoid composition. 2000 X.

Molded Gears vs. Cast

Compare the foregoing machining operations with those necessary on a conventional cast iron gear: *Sixty-four* per cent of the material in the cast iron blank must be hobbed out in making this gear by casting-and-machining.

This saving in raw materials is but one of the cost or quality factors that contribute to the superiority of the molded gear. For example, accuracy of tooth shape is vital to pumping efficiency; the sintered gear follows the involute curve exactly whereas the cast-and-hobbed gear shows some deviation.

Again, the quietness of operation of the gear is a function of its surface finish. Tests with a Brush surface analyzer show the surface of a machined cast iron gear to be much less smooth than that of a sintered gear. A further aid to noiselessness provided by the sintered iron gear is the oil-cushion formed by the oil-filled pores at its surface. Incidentally, the porosity of a sintered gear causes its weight to be 25 per cent less than if it had been cast and machined to the same dimensions.

The mechanical properties of the sintered gear are similar to those of ordinary cast iron. Generally speaking, these are adequate since the gears are not heavily loaded and the service is not at all severe—the most important physical considerations are those of shape-accuracy and surface qualities. If the mechanical properties needed to be improved, heat treatment (hardening) could be employed since the structure of the properly-sintered gear (Fig. 3) is that of an annealed steel, plus the pores (or minus them, as you please). The black spots in the micro are pores left by the graphite when it dissolved and diffused in the iron to form all the carbide that appears in this pearlitic structure.

The manufacture of this oil pump gear by powder metallurgy has resulted in a better gear at a lower cost than by conventional practice and the methods and materials used have been applied on a mass-production scale. Obviously for this job and certainly for many others powder compacts can thus take their place as a metal-form competitive with iron castings, die castings or screw-machine products.

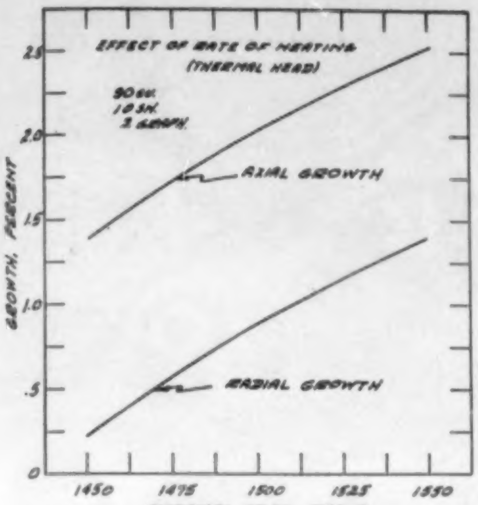


Fig. 4. Graphic demonstration of the powerful effect of rate of heating on the growth of porous bronze briquettes during sintering.

Methods and Equipment

Although powder metallurgy has a design advantage over casting in the *exact size* to which parts can be formed without machining, it is also true that dimensional changes of considerable proportions occur during sintering. The applicability of the powder process thus depends heavily on control of this shrinkage or growth. R. P. KOEHRING of Moraine in his paper "Sintering Methods and Atmospheres for Production Purposes" discussed the factors affecting dimensional change and described production equipment now used for sintering porous bronze bearings and iron gears.

The dimensional change that a part undergoes during sintering varies with the rate at which it is heated. Usually if a briquette of copper, tin and graphite is heated rapidly it will either grow more or shrink less than if heated slowly. A major source of growth may be in the expansion of gases on heating—the gases being air in the pores, adsorbed films on the porous surface, gaseous products of reduced oxide films on the powder particles, etc. If heating rate can be controlled, the rate of gas evolution and thus the growth of powder briquettes can be controlled during sintering.

In other words, after all the pre-sintering variables—powder grades, size distribution, mixture compositions, briquetting pressures, etc.—are controlled, a certain amount of control in the sintering operation itself is still imperative. Continuous "zoned" furnaces are thus highly desirable, for with them the all-important "thermal head" or rate of heating can be adjusted and controlled accurately. The effect of thermal head, as represented by the temperature of the first zone in such a furnace, on the growth of porous bronze briquettes is shown in Fig. 4.

One suitable furnace described is divided into 3 zones of temperature control, and the first zone, at the charge end, is further separated from the rest of the furnace by a dividing wall. A large part of the heating capacity of the furnace is placed in this zone so that the work will come up to temperature quickly and at a controlled rate. The dividing wall aids in maintaining a large temperature difference between the zones when desired. If heavy parts are being sintered, for example, the temperature of the first zone is increased.

Much descriptive material about "Sintering Furnaces and Atmospheres" was also presented by General Electric's H. M. WEBBER, who stressed the adaptability of modern electric brazing furnaces to powder metallurgy work.

KOEHRING (see Fig. 5) showed that behavior during sintering was affected by briquetting conditions and LENEL and HALL mentioned the limitations imposed on powder practice as a fabricating operation by factors associated with pressing—particularly the need for larger automatic presses to overcome size limitations, and for automatic presses that press in more than one direction to overcome shape limitations.

Modern presses and their auxiliaries were described by L. H. BAILEY of Stokes Machine Co. in a paper "Dies and Presses in Powder Metallurgy." Many of the problems of pressing stem directly from friction within the powder mass and from sticking of the powder on the sides of the chamber or on the punch faces. To overcome this, 1-2 per cent of graphite or stearic acid is customarily incorporated in the mix. This admixture need be only ¼ per cent if the lubricant be one of the newer hydrogenated vegetable oils. (One such, "Sterotex," manufactured by Capital City Products Co., Columbus, O., was mentioned).

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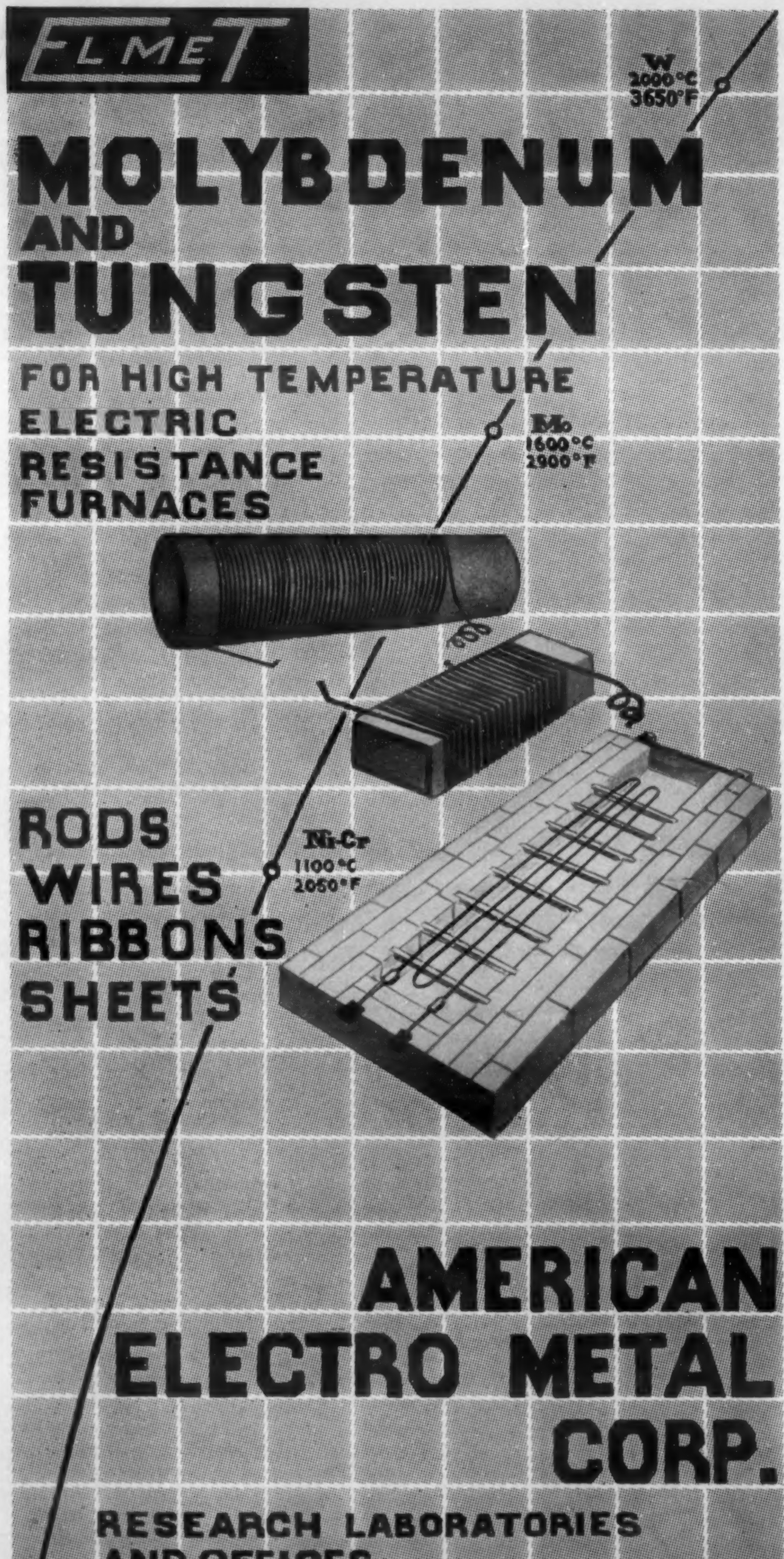

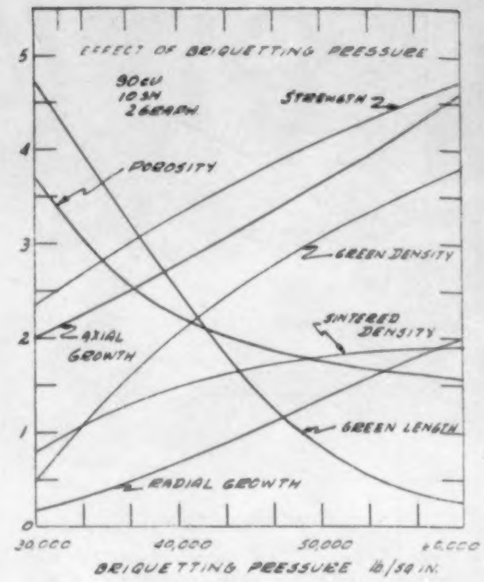

Fig. 5. Schematic diagram showing the effect of briquetting pressure on the physical properties of green and sintered copper-tin-graphite mixtures for bearings. Other curves in Koehring's paper demonstrated that time of sintering had no significant effect on properties and dimensional change but that increasing sintering temperature was characterized by a sudden change of slope for several of the curves at about 1500 deg. F., indicating the beginning of formation of a liquid constituent.

Other Processing Data

The advantages and potentialities in hot pressing (simultaneous pressing and sintering) non-porous products whose mechanical properties are required to be high, and in plastic working of powder compacts generally were reviewed by C. G. GOETZEL of American Electro Metal Corp. A mass of original data and much already-published work were offered as evidence that notable improvement in strength and ductility can be achieved by plastic deformation during or after sintering.

Other papers that contained a wealth of useful processing data in graphic form were "Powdered Copper-Tin Sintering Studies" by J. E. DRAPEAU, JR. of Metals Refining Co., and "Sintering Characteristics of Various Copper Powders" by the same author. All copper powder grades studied shrunk when compacts made of them were sintered for less than 1 hr. at any temperature between 1100 and 1700 deg. F. L. W. KEMPF of Aluminum Co. of America reported in "Properties of Compressed and Heated Aluminum Alloy Powder Mixtures" that compacts made from aluminum, magnesium and zinc powders showed excellent strength after sintering and could have their properties further improved by subsequent aging.

Some of the problems attendant on the classification of raw material powders were discussed in papers by D. O. NOEL of Metals Disintegrating Co. on "Powder Production and Classification" and by J. KURTZ & M. F. ROGERS of Callite Tungsten Corp. on "Classification and Determination of Tungsten and Tungsten Carbide Powders for Production Control." One interesting point was brought out in discussion of the latter—that tungsten particles ball-milled to 1/8 their original size are not significantly different from the same un-milled powders, but particles that were originally reduced (chemically) to the small size do behave quite differently.

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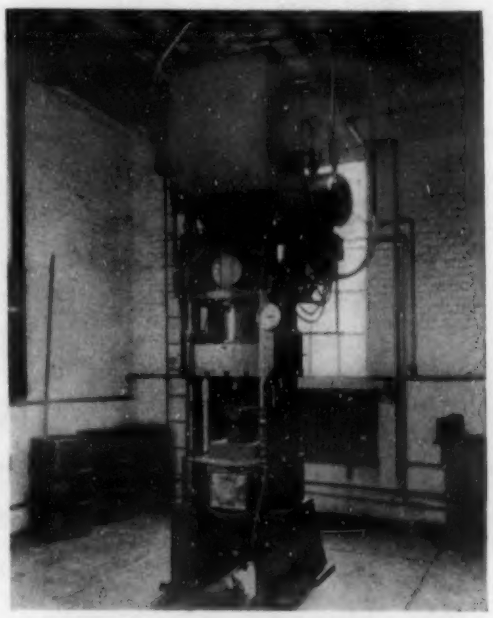


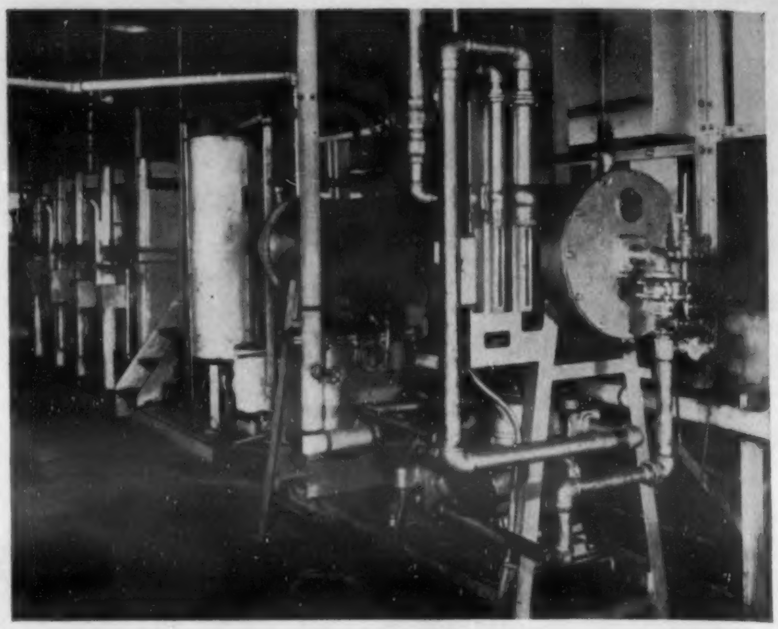


Fig. 6. A combustion type atmosphere generator employed in the production of controlled atmospheres for sintering furnaces. Koehring explained that copper and its alloys can be sintered in any "reducing" atmosphere produced by this generator, provided only that free oxygen be absent. "Richer" reducing atmospheres, low in water vapor, are required for iron-carbon alloys—at about 2000 deg. F. an atmosphere containing 10% CO and 5% CO_2 is satisfactory.

The Future

This review has consciously emphasized the engineering design phase of the subject—the competitive nature of powder compacts as a metal form. This is simply a reflection of authoritative opinion. In the epilogue to his paper HALL said the outstanding trend in powder metallurgy "is its use in displacing established, conventional methods of manufacture of parts."

The product and process-design factors to be met are tremendous, particularly the development of bigger, more powerful presses for making more complicated parts, and the accumulation of data on shrinkage, growth and structure that will permit designers to design on something other than cut-and-try procedures.

Therein, declared E. S. PATCH of Moraine in the final paper, "Industrial Limitations of Powder Metallurgy," lies the wisest course of action for those vitally concerned with powder metallurgy. Improve the quality of compacts, yes, but even more important, eliminate the secrecy that has hampered the exchange of processing data among powder metallurgy's engineers. Powder metallurgy as a fabricating process is growing by leaps and bounds, but the speed with which it approaches the mature status of the more familiar production methods will depend on how much information engineers have that will permit them to "design for powder metallurgy" as well as for other fabricating processes.

Editor's Note—During the last three years METALS AND ALLOYS has published a long string of articles on powder metallurgy. Because readers of this review may be interested in studying some of these previous publications, we are listing below their titles and the issues in which they appeared:

"Copper-Lead Bearings from Metal Powder," by E. Fetz—Sept. 1937, p. 257.

"The Hydride Process," by P. P. Alexander—Sept. 1937, p. 263; Feb. 1938, p. 45; July 1938, p. 179; Oct. 1938, p. 270.

"Symposium on Powder Metallurgy," by F. P. Peters—Mar. 1938, p. 69.

"Possibilities of High Pressures in Powder Metallurgy," by W. D. Jones—May 1938, p. 125.

"Sintering of Copper and Tin Powders," by H. E. Hall—Oct. 1939, p. 297.

"Powder Metallurgy," by F. P. Peters—Oct. 1939, p. A 76.

"Powder Metallurgy of Copper," by C. G. Goetzel—July 1940, p. 30; Aug. p. 154.

"The Iron Powder Situation," by A. T. Fellows—Sept. 1940, p. 288.

METALLURGICAL ENGINEERING news

Equipment
Finishes
Materials
Methods
Processes
Products

Alloys
Applications
Designs
People
Plants
Societies

THE BOTTLENECKS WE WATCH

There seems to be no doubt that American industry — amortization uncertainties notwithstanding—is going ahead rapidly with its plans for more and bigger plants, and with new applications of productivity-improving processes, equipment and tools. Much evidence of this preparedness-inspired activity has accumulated in the last few weeks and the highlights are presented herewith.

Plant Expansions

A host of metal-manufacturing and metal-consuming plants have planned or begun additions to their plant or equipment. According to the *American Society of Tool Engineers,* 53 per cent of all metal-working plants have plans to increase their productive capacity during the last half of 1940. Probably the first aircraft manufacturer to break ground in the national defense expansion program was *Glenn L. Martin Co.,* Baltimore, Md., which last month launched the first of a series of factory additions expected to bring its total floor space to around 3,000,000 sq. ft. and will entail the installation of nearly 1 million dollars worth of new machinery and equipment, most of it for working metals.

The expansion program of a large steel foundry, *The Bettendorf Co.,* Bettendorf, Iowa, will cost $500,000 and when complete will provide an ultra-modern layout keyed to mass production methods. New furnaces will be built, conveyor systems installed, chemical and metallurgical laboratories erected, etc. Also we have recently learned that the electric furnace steelmaking capacity of *Republic Steel Corp.* is to be increased by the installation of two 50-ton electric furnaces at its Canton, Ohio, works, with, of course, the associated processing and finishing equipment.

In the non-ferrous field, *Revere Copper & Brass, Inc.,* New York, announces that since the outbreak of the European war last year it has appropriated over $1,500,000 for improvements and additions to its plants and equipment. A large manufacturer of plating equipment and supplies, *Hanson-Van Winkle-Munning Co.,* Matawan, N. J., has started construction on a 66 ft. x 39 ft. addition to its plant. Both the *Haynes Stellite Co.,* Kokomo, Ind., cutting and wear-resistant alloy producers, and *C. I. Hayes Co.,* furnace manufacturers of Providence, R. I., announce new additions to their manufacturing plants and facilities. And *Mathieson Alkali Works* has well under way the erection of the first of 5 all arc-welded steel buildings at Niagara Falls, according to *Hobart Brothers Co.,* makers of arc welding equipment.

Faster Processing

Production can be increased, too, without building new plants. Figures just released by the *James F. Lincoln Arc Welding Foundation,* Cleveland, show that military, naval and aircraft equipment and the machines for making them could be produced in 30% less time than required with conventional methods if arc welding were fully utilized. Some specific products that have been commercially arc-welded and the savings that are said to have resulted are indicated in the Table.

In our Aug. and Sept. "News" columns we stressed the special utility of carbide cutting tools in increasing the productive capacity of machine tools. According to *Carboloy Co.,* Detroit, however, many engineers do not yet fully realize that there is no reason why older types of machines in good condition cannot be readily adapted to carbide tooling. Particularly for machining steels, the fundamental consideration is that the machine be able to run fast enough—and smoothly at the faster speed.

An "average" cutting speed for such work is about 200 ft. per min. Obviously, it takes more power to run at these higher speeds, but if the machine can handle the horsepower at the higher speed and can be tightened enough to eliminate back-lash and chatter, no trouble should be encountered with cemented carbide tooling.

Incidentally, the *Carboloy Co.* also announced its sixth price reduction on cemented carbides since 1929, together with the beginning of mass production on a standardized line of Carboloy cutting tools —5 styles in 3 grades—that permit pricing complete tools at figures down to 40% of the price for comparable tools in the past. According to the announcement the new standardized tools will be carried in stock, ready for shipment, completely ground and ready for use—including even the grinding-in of chip-breakers on tools to be used for machining steels.

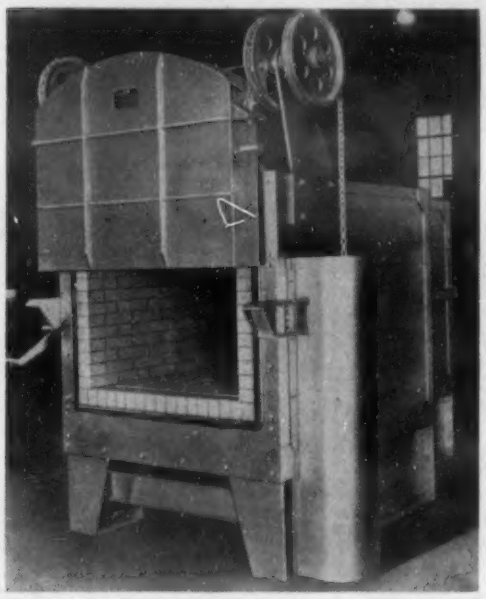
The possible effects of this on engineering buying habits in connection with such tools may be quite drastic. For example, the prices of complete tools may be so low as to decrease the amount of brazing and grinding now done by shops who purchase only carbide tips and make their own complete tools.

Item	*Savings*
9-ft. Anti-Aircraft Combat Car	Elimination of extra parts and manufacturing operations
10,000-ton Cruiser	Saving of 17% in weight, 3% in cost
Submarine Mine Layer	Construction time reduced 25%; 15% savings in weight
Airplane Landing Gear Forks	50% saving in production time; saving of $40 per airplane
Beaching Gear for Large Aircraft	Cost saving of 31.7%; 20% weight saving; production time saving of 20% to 25%
Rotary Planing Machine	89% saving in production time; cost saving of approximately 70%

Box-Type Tempering Furnaces

Lindberg Engineering Co., Chicago, announce the availability of "Cyclone" electric box-type furnaces for production tempering, age-hardening and general low-temperature (up to 1250 deg. F.) heating and preheating operations.

These furnaces utilize the well-known Cyclone forced-convection heating principle, which provides rapid and exactly uniform heating, it is said. The units are built to accommodate heavy production loads such as large gears, forgings, and aluminum alloy parts, as well as ferrous aircraft parts. A heavy cast grid, on which the work can be loaded, is supplied, and the furnace is lined with light-weight refractory insulation.



Heating elements, of high-grade nickel-chromium wire, are easily removed. Standard temperature ranges are 200-850 deg. F. and 200-1250 deg. F. Work-chamber sizes available are from 24 in. wide x 36 in. deep x 18 in. high up to 48 in. wide x 60 in. deep x 30 in. high.

● A new process for welding galvanized steel that involves re-galvanizing at the time of welding is the subject of patents just granted *Artkraft Sign Co.*, Lima, Ohio. Known as "Galv-Weld," the new process can handle sheets of any size and gives a more rust-proof joint than the original galvanized surface, it is claimed.

New Furnace Pressure Controller

Flexibility of installation, convenience of operation and ease of adjustment are the features claimed for a completely redesigned industrial furnace pressure controller just announced by *Leeds & Northrup Co.*, 4934 Stenton Ave., Philadelphia.

Although designed primarily for flush-mounting, the instrument can be supplied for surface-mounting. A selector switch and push button station, enabling the operator to take over manual control at a moment's notice, are built into the controller door. Through the window (in the illustration) just below the handy control setting knob can be seen the stationary pointer and the movable dial.

The new controller combines with a motor-driven interrupter, a relay, signal lights and a motor drive system to form a complete L & N system.

Meetings and Expositions

AMERICAN CERAMIC SOCIETY, Porcelain Enamel Institute Forum, Urbana, Ill., Oct. 16-18.

AMERICAN GEAR MANUFACTURERS' ASSOCIATION, semi-annual meeting. Skytop, Pa., Oct. 14-16.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, fall meeting. Cleveland, Ohio, Oct. 21-23.

AMERICAN PETROLEUM INSTITUTE, annual meeting. Chicago, Ill., Nov. 11-15.

AMERICAN SOCIETY FOR METALS, annual meeting. Cleveland, Ohio, Oct. 21-25.

AMERICAN SOCIETY OF TOOL ENGINEERS, semi-annual meeting. Cincinnati, Ohio, Oct. 17-19.

AMERICAN WELDING SOCIETY, annual meeting. Cleveland, Ohio, Oct. 20-25.

AMERICAN ZINC INSTITUTE, fall meeting of the Galvanizers committee. Baltimore, Md., Nov. 14-15.

FOUNDRY EQUIPMENT MANUFACTURERS ASSOCIATION, annual meeting. Hot Springs, Va., Oct. 25-26.

MEEHANITE RESEARCH INSTITUTE of America, Inc., annual meeting. Milwaukee, Wis., Oct. 30-31, Nov. 1.

NATIONAL METAL CONGRESS AND EXPOSITION, Public Auditorium. Cleveland, Oct. 21-25.

SOCIETY OF AUTOMOTIVE ENGINEERS, national aircraft production meeting. Los Angeles, Cal., Oct. 31, Nov. 1-2.

WIRE ASSOCIATION, annual meeting, Cleveland, Ohio, Oct. 21-24.

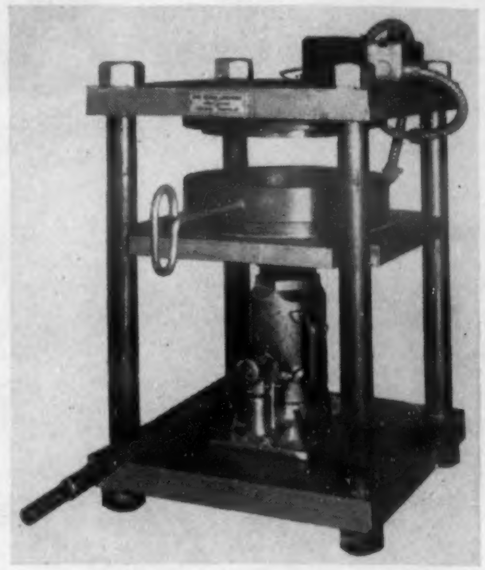
New Sand Testing Equipment

An improved "Moisture Teller" for determining the moisture content of foundry sands and other granular, powdered or fibrous materials is announced by *Harry W. Dietert Co.*, Detroit. In the improved unit is a motor-driven fan, which faces electrically-heated air through the sample being tested, a timer being used to stop the drying process after any desired period. Granular and fibrous materials require 1 to 3 min. while powdered materials and cereals take 5 min.

The same company has also just introduced a new molding sand sampler that is said to be inexpensive, sturdy and most convenient. This new tool—its handle is so long that samples can be taken 24 in. from the outer surface of the sand heap—simplifies the taking of samples from the interior of sand piles or bins. In use it is inserted in the sand, which pushes through the tapered sand container as the sampler is moved toward the interior, insuring a representative sample. When the operator pulls the sampler from the sand, the tapered container grips the sand, and removes 700 grams with each sampling.

Rubber Molds for Casting Metals

An interesting new process for casting white metal for novelty and jewelry products that comprises the use of rubber molds, and which reduces mold cost thereby to 1/10 the cost of previously-used bronze molds, is announced by *Alrose Chemical Co.*, Providence, R. I.



The molds, of newly-developed rubber compounds, are made by placing the models or samples to be duplicated between rubber blanks which are then compressed together to produce the casting cavity. (Illustration shows the vulcanizer.) The hardened rubber molds are then suitable for casting metals that melt below 700 deg. F., on a production basis. Models may be of any metal and require no drafting.

Perfect reproduction of even the finest detail is assured by the use of centrifugal force in casting, it is said. From 15 to 100 gross of castings can be produced from a mold costing less than $5.00. The entire equipment (available from Alrose) can be set up in a 60-in. x 60-in. space.

● Die cast grilles are no longer confined to the automotive industry. According to the *New Jersey Zinc Co.*, New York, the Wurlitzer automatic phonograph grille, formerly sand cast, is now a die casting, and Iron Fireman employs die cast grilles on an attractive new room heater.

Spring Wire Treated by Direct Resistance Heating

Increasing demand for higher and more uniform physical properties in spring wire led to the development of the process by which *Jones & Laughlin Steel Corp.*, Pittsburgh, produces its new Electromatic oil-tempered spring wire. The new process consists of passing enough electric current through the wire to heat it to the desired quenching temperature, so that the full cross section is uniformly and simultaneously heated to this temperature.

The process is carefully regulated to provide a 2-stage quenching operation that is not too drastic, followed by controlled tempering to develop maximum physical and fatigue properties. Wire so treated is said to have applications in various types of automobile and aircraft springs, and in mechanical springs for farm-and-factory machinery.

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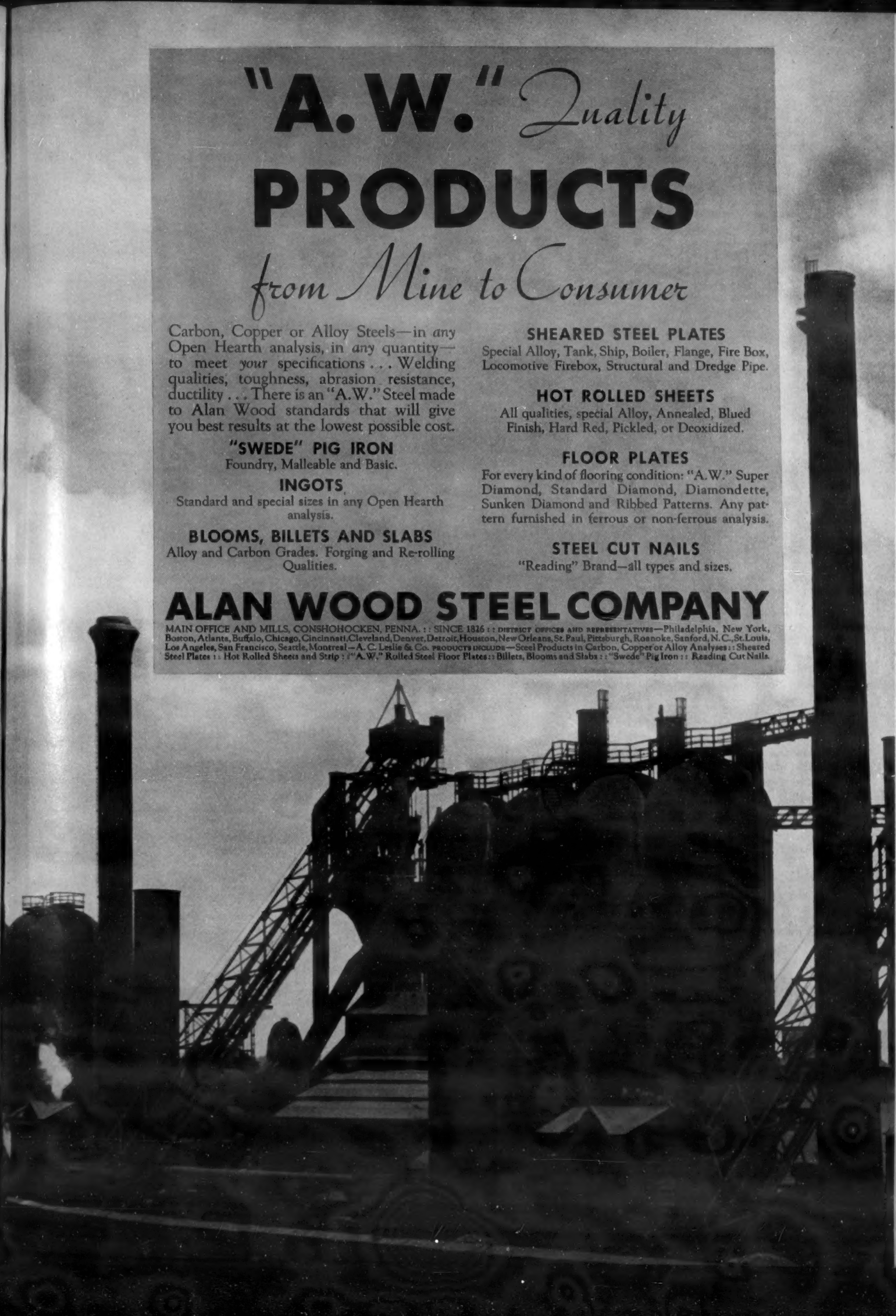

"A.W." Quality
PRODUCTS
from Mine to Consumer
Carbon, Copper or Alloy Steels—in *any* Open Hearth analysis, in *any* quantity—to meet *your* specifications . . . Welding qualities, toughness, abrasion resistance, ductility . . . There is an "A.W." Steel made to Alan Wood standards that will give you best results at the lowest possible cost.
"SWEDE" PIG IRON
Foundry, Malleable and Basic.
INGOTS
Standard and special sizes in any Open Hearth analysis.
BLOOMS, BILLETS AND SLABS
Alloy and Carbon Grades. Forging and Re-rolling Qualities.
SHEARED STEEL PLATES
Special Alloy, Tank, Ship, Boiler, Flange, Fire Box, Locomotive Firebox, Structural and Dredge Pipe.
HOT ROLLED SHEETS
All qualities, special Alloy, Annealed, Blued Finish, Hard Red, Pickled, or Deoxidized.
FLOOR PLATES
For every kind of flooring condition: "A.W." Super Diamond, Standard Diamond, Diamondette, Sunken Diamond and Ribbed Patterns. Any pattern furnished in ferrous or non-ferrous analysis.
STEEL CUT NAILS
"Reading" Brand—all types and sizes.
ALAN WOOD STEEL COMPANY
MAIN OFFICE AND MILLS, CONSHOHOCKEN, PENNA. : : SINCE 1826 : : DISTRICT OFFICES AND REPRESENTATIVES—Philadelphia, New York, Boston, Atlanta, Buffalo, Chicago, Cincinnati, Cleveland, Denver, Detroit, Houston, New Orleans, St. Paul, Pittsburgh, Roanoke, Sanford, N. C., St. Louis, Los Angeles, San Francisco, Seattle, Montreal—A. C. Leslie & Co. PRODUCTS INCLUDE—Steel Products in Carbon, Copper or Alloy Analyses : : Sheared Steel Plates : : Hot Rolled Sheets and Strip : : "A.W." Rolled Steel Floor Plates : : Billets, Blooms and Slabs : : "Swede" Pig Iron : : Reading Cut Nails.

Comparator-Densitometer

Spectrochemical analysis is growing in popularity as a control tool and for research purposes. A simple, compact self-contained comparator-densitometer for measuring the density of lines on spectrogram plates is now available from *Harry W. Dietert Co.,* Detroit.

The instrument provides means for accurately and speedily projecting a spectrogram on a viewing screen, and for identifying the spectral lines of up to 70 elements, it is said. The density is read from the scale of a meter in terms of percentage of

light transmission, automatic motor scanning being employed to measure the light transmission of a spectral line.

New Gas Regulators

Three new single-stage general service regulators—the Oxweld R-80 oxygen regulator for delivery of oxygen at working pressures up to 200 lbs. per sq. in., the Oxweld R-81 for acetylene, and the Oxweld R-82 for fuel gas—are announced by *Linde Air Products Co.,* a unit of Union Carbide & Carbon Corp., 30 E. 42nd St., New York.

The new regulators are designed to give completely dependable performance in all welding, cutting and deseaming operations where simple construction and large capacity are demanded but where the refinements of two-stage regulators are not required. The three regulators are all of the Stem type—that is, the valve closes with the incoming pressure, thus assuring positive seating action.

A new *two-stage* regulator, said to be unusual in that its first stage can be adjusted to various pressures, has been developed by *Alexander Milburn Co.,* 1493 W. Baltimore St., Baltimore, Md. Known as the Type FF "Twin Stage" regulator, the new unit can be used for different operations; after the selected pressure is set, the delivery stage may be adjusted to any desired working pressure up to 200 lbs.—or more—if specified.

The outstanding feature of the Type FF's simplified construction is a unitary valve assembly, which is used in both stages and has only four simple parts. Seating is *with* instead of *against* the pressure. Removable and interchangeable inlets permit adaptation to any tank or line connection for any type of gas. Also, the first stage of the type FF can be purchased separately for converting any make of single-stage regulator into two-stage control.

New Air-Hardening Die Steel

For tool and die applications where initial cost must be held to a minimum and where a non-deforming, easy-machining, tough steel with a wide hardening range is required, *Jessop Steel Co.,* Washington, Pa., offers its Windsor special air-hardening die steel.

This chromium - molybdenum - vanadium steel may be hardened and tempered in either oil or air. Its non-deforming qualities are demonstrated by its use in a die that has 27 holes and 6 large punches employed to punch out clock frames of the greatest accuracy, by the *Lux Clock Mfg. Co.,* Waterbury, Conn., who report no measurable change in the die after heat treatment.

Balancing-Machines and Product Design

From *Gisholt Machine Co.,* Madison, Wis., comes an interesting description of the use of dynamic balancing technique as an adjunct to the design and manufacture of a metal product—in this case a home ventilating fan of the Sirocco type. Static balancing by means of roller-type ways had failed to provide sufficient accuracy of balance to eliminate vibration noises.

A Gisholt type S Dynetric balancing machine is said to have solved economically the problem of controlling unbalance and completely eliminating vibration noises on the entire range of fan sizes to within 0.007 oz. of correction weight. Total time for measuring, locating, correcting and checking unbalance in each fan was only 2.5 min. In addition, the machine uncovered a structural weakness in design that was responsible for many rejections and customers' complaints.

Fans are mounted for balancing on an arbor fitting the hub bore and having the same diameter as the shaft used in ultimate assembly. Balancing is done at actual operating speeds of 750-1800 r.p.m. Correction planes are located in the shroud rings at either end of the fan, and correction is made by adding lengths of 1/8-in. wire solder on the shroud rings. The number of 1/16-in. lengths of solder to be added at each position is read directly from the meter on the machine.

New Oven Pyrometer

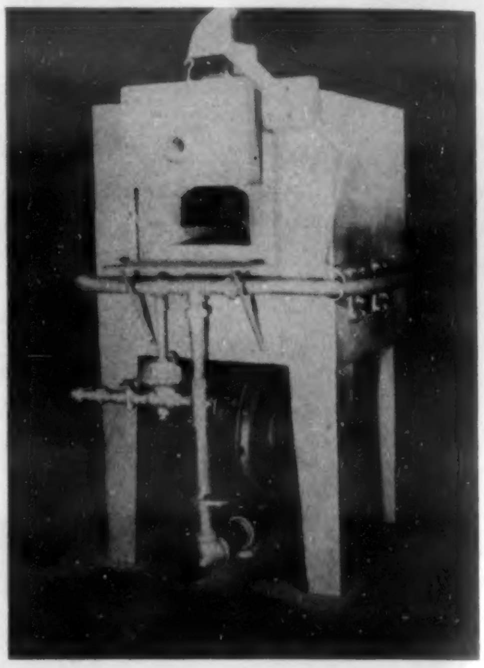
There are many low-temperature heating applications where an inexpensive, convenient-sized indicating pyrometer of reliable accuracy is highly desirable. Many manufacturers and operators of large and small ovens and electrical heating devices will be interested in the new "Alnor" pyrometer, which gives temperature readings in any one of 3 ranges—0-500, 0-600 or 0-800 deg. F.

The instrument, manufactured by *Illinois Testing Labs., Inc.,* Chicago, is a millivolt meter type of pyrometer, with a 2⅝-in. scale. It is offered complete with thermocouple up to 36 in. and manual zero-adjusting screw to permit resetting of the pointer for room or cold-end temperature. The price of the instrument is $22.50 in the 500 deg. F. range and $21.50 for the higher ranges. An internal cold-end compensator can be furnished at extra cost.

New Tool Furnace

Developed especially to meet the demand for a low-cost furnace having positive combustion control, the new Mahr tool furnace has a combustion chamber designed to give uniform heat throughout the hearth area at any temperature desired for any treatment of the various steels.

The manufacturer, *Mahr Mfg. Co.,* Minneapolis, Minn., reports that a new, improved control eliminates guessing, and assures reproducible results. The special proportional air-gas mixer has a vernier control gradu-



ated for easy and quick setting. A record chart of results desired permits instant settings for future repeat operations.

The furnace is gas-underfired and is equipped with 4 premixed gas burners arranged for single valve control—with or without blower. Its size is 12 in. x 18 in. x 6 in.

Nitrided Stainless Steels

Additional data on nitrided stainless steels, described for the first time in our Sept. issue, pp. 271-273, have just been issued by *Drever Co.* of Philadelphia and *Industrial Steels, Inc.* of Cambridge, Mass., joint sponsors of the process.

The process, known as the Drever-Industrial Stainless Nitriding Process and said to provide a nitrided case with hardness up to 93 Rockwell 15N on stainless steels, leaves the material with practically the same corrosion resistance as the unnitrided stainless steel. Nitrided 18 and 8, for example, shows a "B plus" rating in the ASTM salt-spray test and nitrided samples of both chromium-iron and chromium-nickel-iron have "A" ratings in gasoline, kerosene and fuel oil. Steam impingement tests are said to show no case deterioration of the nitrided surface after 100 hrs.

● "Resistance forge-welding" is the name given by *Progressive Welder Co.,* 3081 E. Outer Drive, Detroit, to their new process of heavy-duty spot welding heavy (up to 1-in.) steel and iron sections, which comprises applying pressure to the work, then passing interrupted current, and finally superimposing a hammering action on the electrode.

(Continued on page 486)

New Furnace Atmosphere

A new furnace atmosphere consisting largely of carbon monoxide and nitrogen and known as "drycolene" has been developed by engineers of *General Electric Co.*, Schenectady. The new atmosphere is said to be completely free of carbon dioxide, water and oxygen and is ready for delivery to the furnace without further treatment.

The atmosphere is described as suitable for scale-free hardening, bright annealing, sintering and electric-furnace brazing of high-carbon steels without decarburization, carburization or oxidation. It is obtained from the G-E drycolene producer, in which dried products of fuel-gas combustion are passed over incandescent charcoal in a retort, the effluent gas being the controlled atmosphere.

● A new tonnage indicator for Steelweld bending presses (manufactured by *Cleveland Crane & Engineering Co.*, Wickliffe, Ohio) keeps both operator and management informed of press loadings and gives warning when the dies are worn.

New Spot Welders

As companion lines to the recently announced types 0 and 1 foot-operated "Hot Spot" welders (see our Sept. issue, p. 304), the *Acme Electric Welder Co.*, Huntington Park, Cal., is bringing out foot-operated rocker arm "Hot Spot" type 2 in 20 and 30 kva. transformer capacities and type 3 in 40 and 50 kva. transformer capacities.

Housings are all-welded steel, horns are double and reversible, and clamping block devices are provided to retain the horns in their holders with perfect electrical contact, yet capable of instant release.

● Electroplating on aluminum and its alloys is said to be made possible by a 2-4 min. non-electrolytic dip in a solution known as "Pre-Plate," furnished by *Colonial Alloys Co.*, E. Somerset, Trenton Ave & Martha Sts., Philadelphia.

New D.C. Arc Welder

A new 200-amp. d.c. arc welder of *General Electric Co.*, Schenectady, N. Y., will provide any welding current from 25 to 250 amps. and, it is said, will allow all-day manual welding to be done with currents up to 200 amps. using electrodes 1/16 to 3/16 in. diameter. Electrodes as large as ¼ in. can be used on occasional short jobs.

Two outstanding features claimed for the new welder are (1) that it prevents time-wasting arc pop-outs by providing for instant recovery of the voltage to an extent greater than the arc voltage after each short circuit, and (2) that it never allows current peaks to exceed 3 times the steady short-circuit current on any adjustment, thus preventing excessive heat and spatter.

● An interesting application of stainless-clad steel is a mixing tank fabricated by *L. O. Koven & Bros., Inc.*, Jersey City, from Jessop type 306 Silver-Ply steel plates supplied by Jessop Steel Co., Washington, Pa. The plates on this particular job consisted of 0.086 in. of stainless steel cladding on 0.351 in. of mild steel backing.

Tongs for Handling Ingots, etc.

In plants where materials have to be handled by cranes or hoists, the use of Gellert Tongs, now produced exclusively by *Heppenstall Co.*, Pittsburgh, are said to decrease safety hazards and to cut lost time to a minimum. The Gellert Tongs are simply lowered on the work, and then do their

job automatically. The craneman has entire control, and ground men do not have to throw chains around hot ingots or forgings, nor climb to the top of scrap piles with danger of slipping or being crushed by material rolling down.

Several types of these tongs are in successful operation in steel mills and foundries for handling ingots, ingot molds, die blocks, pipe, and wire; other special designs are made for non-ferrous metal ingots or shapes. Lifting capacities run as high as 200,000 lbs. The working parts of the tongs are made of a nickel-chromium-molybdenum steel corresponding to S.A.E. 4340, heat treated to provide ample strength along with toughness to resist shock loads.

News of Metallurgical Engineers

C. H. Manion, since 1932 chief engineer of Follansbee Steel Corp., Pittsburgh, has been elected vice-president in charge of operations. His place has been taken by *Wm. L. Barr*, erstwhile maintenance engineer . . . . *L. E. MacFayden* has been appointed superintendent of the High Bridge plant of Taylor-Wharton Iron & Steel Co. . . . . *Daniel E. Igo* recently joined Graver Tank & Mfg. Co., E. Chicago, Ind., as sales and promotion engineer on fabricated stainless and composite steels.

With the new year *J. B. Neiman*, Detroit plant manager of Federated Metals Div. of American Smelting & Refining Co., will become general manager of the company's country-wide aluminum operations . . . . *H. E. Ardahl*, formerly chief metallurgist of John Deere Tractor Co., has been appointed assistant to the vice-president of Michiana Products Corp., Michigan City, Ind. . . . . *H. R. Schofield*, formerly chief engineer of Leeds & Northrup Co., Philadelphia, has been appointed director of engineering, and J. W. Harsch takes his place as chief engineer . . . .

J. C. Hodge, until now chief metallurgist of Babcock & Wilcox Co., has been elected vice-president and director of Wellman Engineering Co., Cleveland . . . . *C. J. Miller*, president of Fremont Foundry Co., has been elected president of the Gray Iron Founder's Society, Inc., and W. W. Rose was re-elected executive vice-president.

Claire C. Balke, for the past year active in establishing a new powder metallurgy department at Stevens Institute of Technology, has rejoined the research staff of Fansteel Metallurgical Corp., North Chicago. . . . *Corbin T. Eddy's* promotion from associate professor in metallurgy and mineral dressing to professor and head of the department of metallurgical engineering is announced by Michigan College of Mining and Technology, Houghton, Mich. . . . *Anthony W. Deller* has been named patent counsel for the International Nickel Co. to head the company's newly created patent department. . . .

Melville Lowe, for the last 10 yrs. metallurgist with Hevi Duty Electric Co., Milwaukee, has established a metallurgical consultant service in connection with the Anderson Laboratories, 3920 W. National Ave., Milwaukee. . . . *Lincoln T. Work*, associate professor of chemical engineering, Columbia University, New York, has been appointed director of research, Metal and Thermit Corp., New York.

Free Service Department

Replies to box numbers should be addressed care of METALS AND ALLOYS, *330 W. 42nd St., New York.*

POSITION WANTED: Powder metallurgist with five years' experience in research and production development of metal powder products, mainly bearing and contact materials, wishes to extend his experience by entering into broader fields of investigation of compacting, heat treating and subsequent adaptation to commercial requirements of metal powder products. Married. Prefer Midwestern territory. Box MA-24.

POSITION WANTED: Chemist-Librarian. Young man, Harvard-trained, with experience in analysis of glass and refractories and particularly in translating and abstracting foreign technical literature. Reads Russian, French, German; now an abstractor for METALS AND ALLOYS, Chemical Abstracts, Ceramic Abstracts, and industrial firms. Box MA-25.

POSITION WANTED: Graduate metallurgist, age 25. Four years of practical experience in physical metallurgy; consisting of metallography, laboratory, development, field problems, etc., on a wide variety of ferrous and non-ferrous metals and alloys. Now employed. Box MA-26.

HELP WANTED: Recent young engineering graduate for work in ferrous research laboratory. Native born American. Location Philadelphia district. Reply giving age, education, experience and salary expected. Box MA-27.

HELP WANTED: Opening available for manufacturers' representatives to handle the sale of atmosphere furnace equipment in Detroit, Cleveland, Philadelphia and Buffalo. Box MA-28.

HELP WANTED: The following territories are open for representation of manufacturer of metal heating equipment: St. Louis, Chicago, Cincinnati and Philadelphia. Box MA-29.

POSITION WANTED: Powder metallurgist: B. S. 1934, Ch. E. 1936; age 27, single. Two years in manufacture and production control of cemented carbides for wire drawing dies by hot-press method. Two years in general powder metallurgy research including electric furnace and die design. Box MA-30.

PREVIEW SECTION

of the

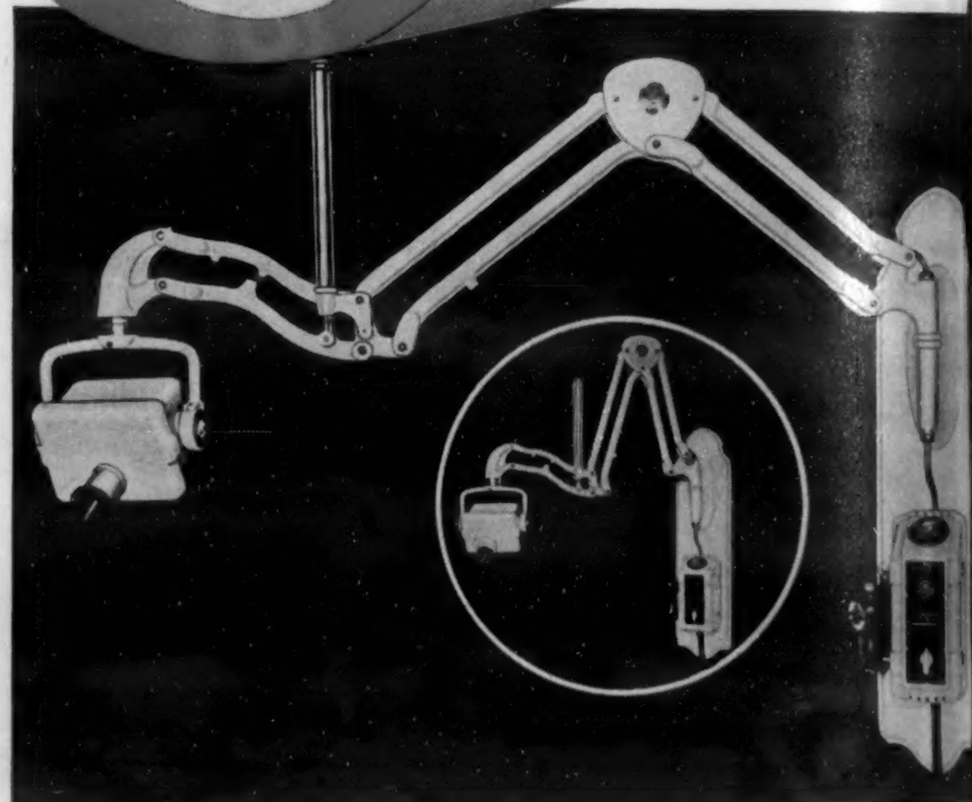
NATIONAL METAL CONGRESS

MAKES FLEXIBLE EQUIPMENT EASIER TO OPERATE!

The Fisher Wall-Mounted Dental X-Ray Apparatus is designed with flexible extension arms so that it can be instantly adjusted to any position.

These arms are made of DOWMETAL*, which is an alloy of Mg (magnesium)—a metal that is a full third lighter than any other in common use. In thus eliminating useless weight the designers attained a maximum ease of operation—an advantage highly desirable in dental work.

This is just one more example of the wide-spread acceptance of DOWMETAL Magnesium Alloys for varied applications. Amazing lightness, together with exceptional durability and toughness, make magnesium (Mg) the most useful of all structural metals.



The flexible extension arms of this Fisher Dental X-Ray Apparatus are made of DOWMETAL Sand Castings by Hills-McCanna Co. They eliminate weight and assure ease of adjustment.

DOWMETAL Magnesium Alloys are available in sand, die and permanent mold castings, forgings, sheet, strip, plate, bars, tubes, structural and special extruded shapes. Write for any information desired.

DOWMETAL

MAGNESIUM ALLOYS

LIGHTEST OF ALL STRUCTURAL METALS

THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN

Branch Sales Offices: New York City, St. Louis, Chicago, San Francisco, Los Angeles, Seattle.

*Trade Mark Reg. U. S. Pat. Off.

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● Armor plate, aeroplane parts, shells, cartridge cases, bombs, gun barrels and mounts—the numerous component parts used in tractors, tanks, trucks, etc., in fact, every metallic item used for defense and all equipment used in their fabrication require Heat Treating.

Navy

SPEED UP

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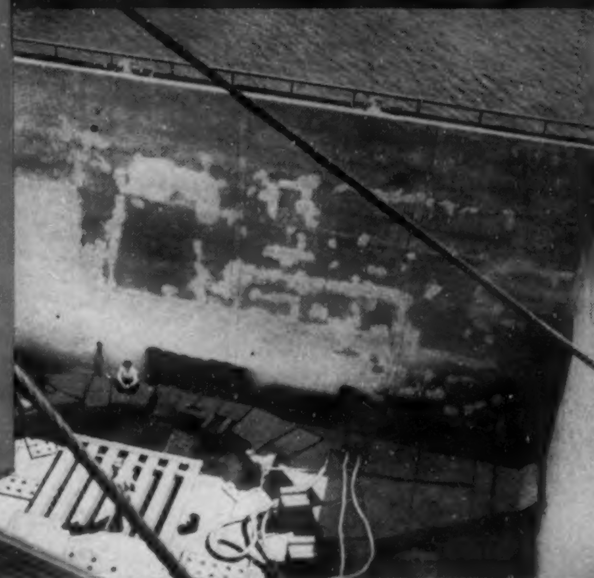

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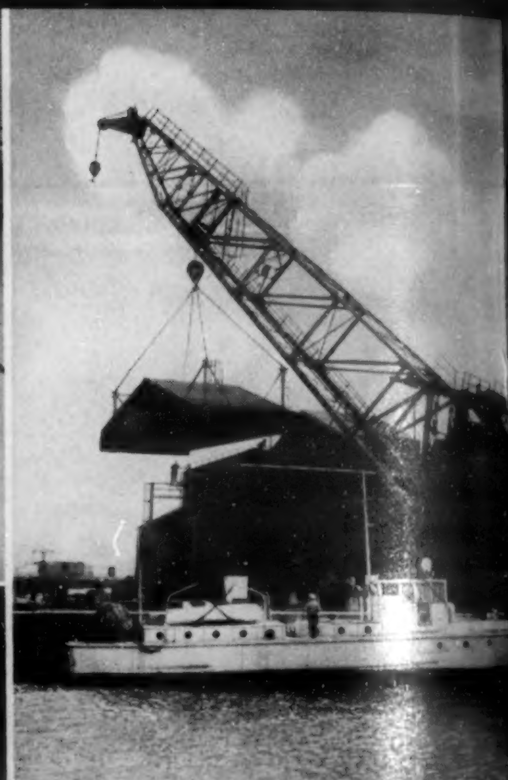

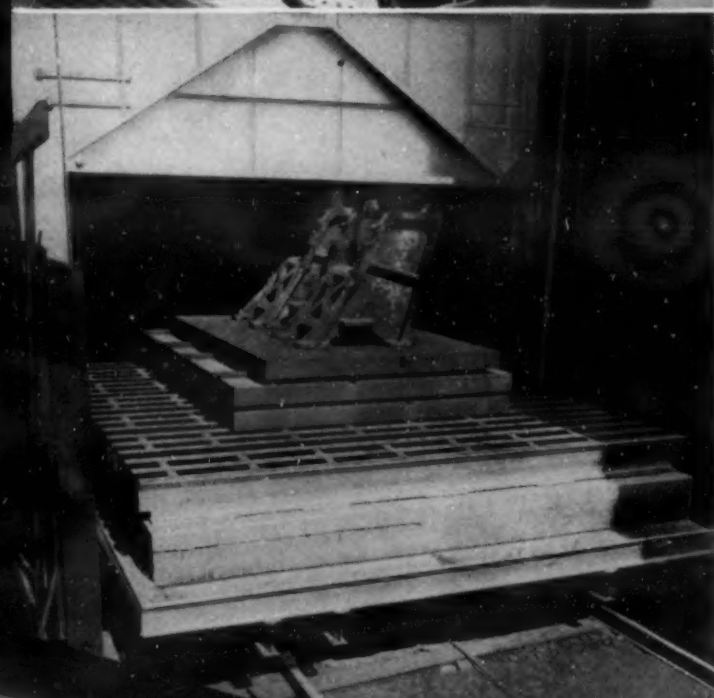

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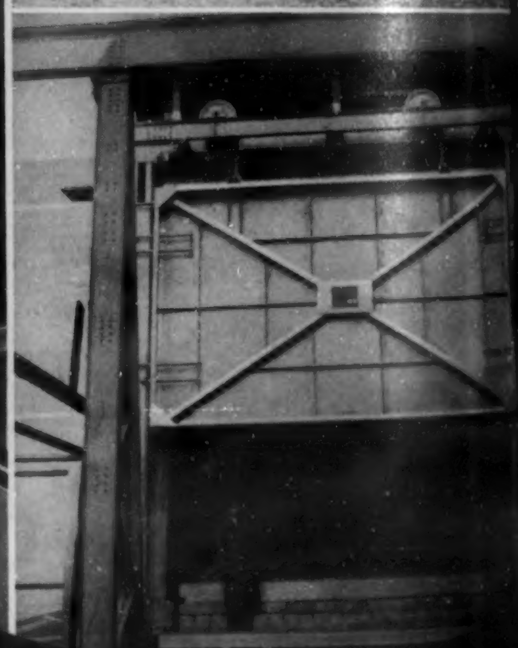

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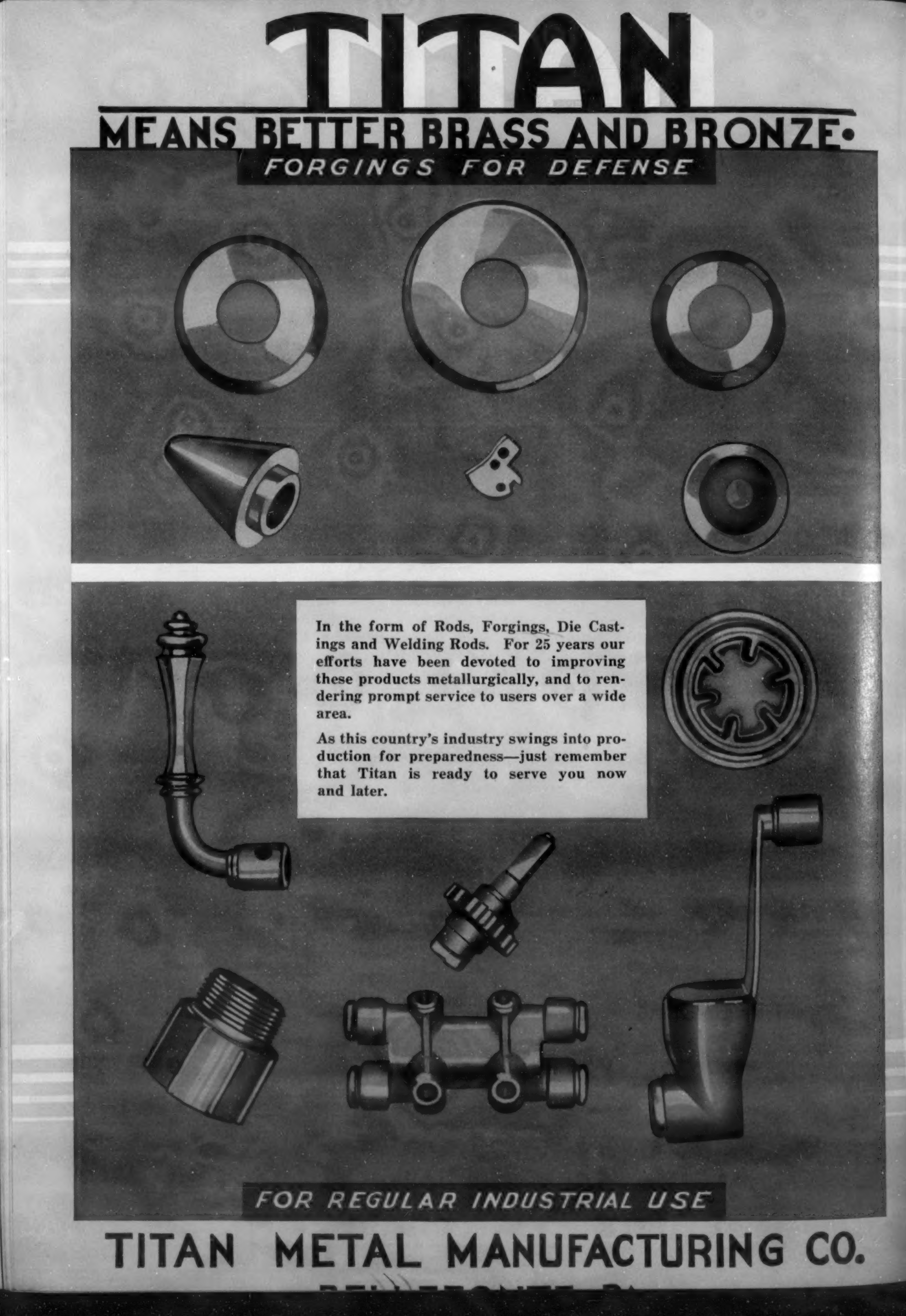
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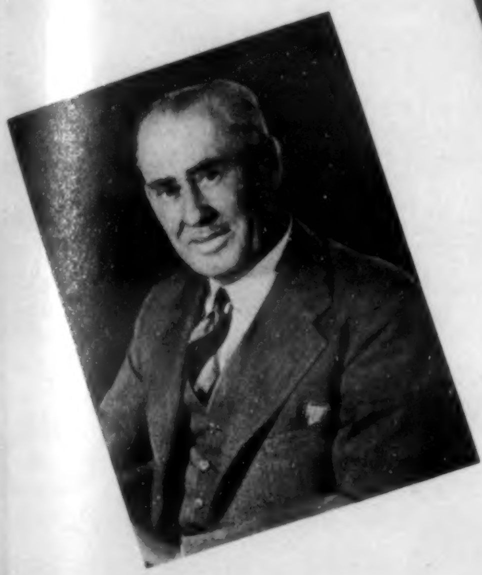
MEANS BETTER BRASS AND BRONZE•
FORGINGS FOR DEFENSE
In the form of Rods, Forgings, Die Castings and Welding Rods. For 25 years our efforts have been devoted to improving these products metallurgically, and to rendering prompt service to users over a wide area.
As this country's industry swings into production for preparedness—just remember that Titan is ready to serve you now and later.
FOR REGULAR INDUSTRIAL USE
TITAN METAL MANUFACTURING CO.

INTRODUCTION

JAMES P. GILL
PRESIDENT—A.S.M.



O. E. HARDER
VICE-PRESIDENT—
A.S.M.

Public Auditorium—Cleveland—This will house the National Metal Exposition

THE NATIONAL METAL CONGRESS is an event looked forward to each year with keen anticipation by metallurgists, metallurgical engineers, and others in the U. S., Canada, and elsewhere. This year it will be held in Cleveland—Oct. 21 to 25 inclusive. General headquarters are the Statler Hotel—the Exposition will be held in the spacious Public Auditorium.

Preliminary announcements indicate that this year's affair—the 22d Congress—will be the largest in its history.

The Participating Societies

For a number of years—and this is true this year—four technical societies cooperate in making the Congress a success: The American Society for Metals which sponsors the Congress, the American Institute of Mining & Metallurgical Engineers (the two metal divisions), the American Welding Society, and the Wire Association.

During the 5-day convention these four societies have scheduled over 150 papers, lectures and discussions—presented by prominent metallurgists, metallurgical engineers, industrialists and scientists. Symposiums, or some special feature, characterize most of the programs.

The Exposition

The National Metal Exposition this year is reported to be the largest ever held—at least 20 per cent larger than the one in Chicago last year. Nearly all of the spacious available floor room in the Cleveland Public Auditorium has been reserved. The total number of exhibitors approaches 275, occupying more than 100,000 sq. ft.

A "theme" has been selected for this year's show—"New Aids to Production"—tying in with the Government's Defense Program.

Lectures

The main feature in the scheduled lectures is the Campbell Memorial Lecture—delivered this year by Dr. S. L. Hoyt of Battelle Memorial Institute—on Wednesday morning, Oct. 21.

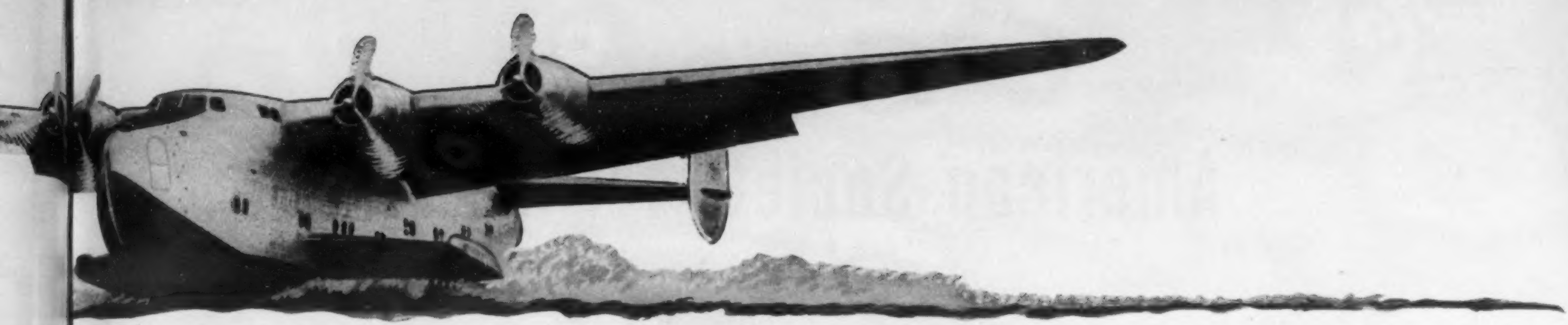
Continuing a custom established 5 yrs. ago, a series of educational lectures will be delivered—one on "The Strength of Metals Under Combined Stresses" by Maxwell Gensamer, Carnegie Institute of Technology, and the other on "Quenching in Heat Treating." The first series consists of five lectures; the second of three by different authorities.

Other lectures have been arranged for by some of the other societies.

In General

Plant visitations have been scheduled; the Cleveland territory is rich in metal-working plants, ferrous and non-ferrous.

On other pages will be found the tentative technical programs of each society. A list of the exhibitors at the Exposition, as of Sept. 5, is also published.



ALLOY

RFACE FOR WEAR RESISTANCE!

drive couplings (illustrated here)—because according to Pump Engineering's chief engineer "It wears longer than any other similar material even with no lubrication other than what little may be derived from the fuel passing through the pump."

Nitralloy is also used in the cylinder barrels, gears and other important parts of the clipper's motors because Nitralloy presents a minimum of distortion and a maximum of wear resistance along with its tremendous durability. Just another of the many phases of industry that has accepted Nitrided Nitralloy to give longer life to vital machine parts.

For information write the Nitralloy Corporation or any of its listed licensees.

THE NITRALLOY CORPORATION

230 Park Avenue — ***New York, N. Y.***

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Companies Licensed by The Nitralloy Corporation

Allegheny Ludlum Steel Corp.	Watervliet, N. Y.
Bethlehem Steel Co.	Bethlehem, Pa.
Crucible Steel Co. of America	New York, N. Y.
Firth-Sterling Steel Co.	McKeesport, Pa.
Republic Steel Corporation	Cleveland, Ohio
The Timken Roller Bearing Co.	Canton, Ohio
Vanadium-Alloys Steel Co.	Pittsburgh, Pa.

★ ★ ★

Operating and Accredited Nitriding Agents

Camden Forge Co.	Camden, N. J.
Commercial Steel Treating Corp.	Detroit, Mich.
The Lakeside Steel Improvement Co.	Cleveland, Ohio
Lindberg Steel Treating Co.	Chicago, Ill.
Link-Belt Co.	Philadelphia, Pa.
Met Lab, Inc.	Philadelphia, Pa.
New England Metallurgical Corp.	Boston, Mass.
Pittsburgh Commercial Heat Treating Co.	Pittsburgh, Pa.
Queen City Steel Treating Co.	Cincinnati, Ohio
Wesley Steel Treating Co.	Milwaukee, Wis.
Ontario Research Foundation	Toronto, Ontario, Canada

Technical Program of the

American Society for Metals

A LEADING FEATURE OF THE WEEK'S technical feast is the program of the sponsoring society, the A. S. M.

The schedule this year calls for over 67 papers during 14 sessions, including lectures and a symposium on "Surface Treatment of Metals." The sessions commence on Monday morning, Oct. 21, and continue each day through Friday, Oct. 25, some being simultaneous. These sessions and lectures will be held in the Statler Hotel in the morning, with the afternoon and evening sessions in the comfortable meeting rooms of the Public Auditorium.

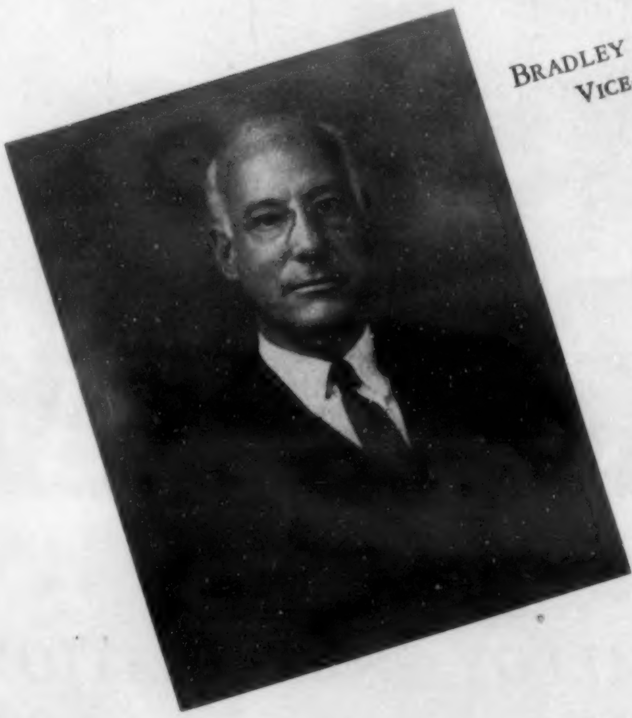
Besides the symposium referred to, highlights of the program include a series of five lectures on "The Strength of Metals under Combined Stresses" by Dr. Maxwell Gensamer of Carnegie Tech. and three lectures on the general subject of "Quenching in Heat Treating" by authorities in that field.

The Campbell Memorial Lecture is the chief technical event of the week. It will be delivered this year by Dr. S. L. Hoyt of Battelle Memorial Institute, Columbus, Ohio.

The annual banquet is scheduled for Thursday evening, Oct. 24, at the Hotel Statler.

The tentative technical program for the 5-day convention is as follows:

BRADLEY STOUGHTON VICE-PRESIDENT ELECT



S. L. HOYT CAMPBELL MEMORIAL LECTURER

MONDAY, OCT. 21

"Correlation of High Temperature Creep and Rupture Test Results," by R. H. Thielemann, General Electric Co.

"The Development of Alloys for Use at Temperatures Above 1000 Deg. F.," by E. R. Parker, General Electric Co.

"The Significance of Hydrogen in the Metallurgy of Malleable Cast Iron," by H. A. Schwartz, G. M. Guiler and M. K. Barnett, National Malleable & Steel Castings Co.

"Factors Affecting the Activity of Carburizing Compounds," by M. Sutton, Standard Oil Co. of Indiana, and R. A. Ragatz, University of Wisconsin.

"A Balanced Protective Atmosphere—Its Production and Control," by J. R. Gier, Westinghouse Electric & Mfg. Co.

"Furnace Atmosphere Generation," by Sam Tour, Lucius Pitkin, Inc.

"Dimensional Changes on Hardening High Chromium Tool Steels," by H. Scott and T. H. Gray, Westinghouse Electric & Mfg. Co.

"Water Vapor in Furnace Atmosphere," by Sam Tour, Lucius Pitkin, Inc.

Educational Lectures

5:00 P.M.—*"The Strength of Metals Under Combined Stresses,"* by Maxwell Gensamer, Carnegie Institute of Technology.

8:30 P.M.—*"Principles of Quenching,"* by A. A. Bates, Westinghouse Electric & Mfg. Co.

TUESDAY, OCT. 22

"Transformation of Austenite on Continuous Cooling and Its Relation to Transformation at Constant Temperatures," by R. A. Grange and J. M. Kiefer, United States Steel Corp.

"Influence of Austenitic Grain Size on the Critical Cooling Rate of High-Purity Iron-Carbon Alloys," by T. G. Digges, National Bureau of Standards.

"Dilatometric Studies in the Transformation of Austenite in a Molybdenum Cast Iron," by D. B. Oakley and J. F. Oesterle, University of Wisconsin.

"Effect of Rate of Heating Through the Transformation Range on Austenitic Grain Size," by S. J. Rosenberg and T. G. Digges, National Bureau of Standards.

"Recovery of Nickel from Cold Working on Annealing," by Erich Fetz, Wilbur B. Driver Co.

"Structural Changes in Low Carbon Steels Produced by Hot and Cold Rolling," by N. P. Goss, Cold Metal Process Co.

(Continued on page 502)

(Continued from page 498)

"Quantitative Measurement of Strain Hardness in Austenitic Manganese Steel," by D. Niconoff.

"Equilibrium Relations in the Solid State of the Iron-Cobalt System," by W. C. Ellis and E. S. Greiner, Bell Telephone Laboratories.

"The Effect of Molybdenum and Columbium on the Structure, Physical Properties and Corrosion Resistance of Austenitic Stainless Steels," by R. Franks, W. O. Binder and C. R. Bishop, Union Carbide & Carbon Research Laboratories.

"Kinetics and Reaction Products of the Isothermal Transformation of a 6 Per Cent Tungsten, 6 Per Cent Molybdenum High Speed Steel," by J. L. Ham, R. M. Parke and A. J. Herzig, Climax Molybdenum Co.

"Some Surface Studies on Treated High Speed Steel," by J. G. Morrison, Landis Machine Co.

"Surface Carbon Chemistry and Grain Size of 18-4-1 High Speed Steel," by W. A. Schlegel, The Carpenter Steel Co.

Educational Lectures

5:00 P.M.—*"The Strength of Metals Under Combined Stresses,"* by Maxwell Gensamer, Carnegie Institute of Technology.

8:30 P.M.—*"Quenching in Production Heat Treating,"* by W. J. Conley, University of Rochester.

WEDNESDAY, OCT. 23

1940—Edward de Mille Campbell Memorial Lecture, by S. L. Hoyt, Battelle Memorial Institute.

"The Technique of Microradiography and Its Application to Metals," by G. L. Clark and W. M. Shafer, University of Illinois.

"Quantitative Evaluation of Distortion in Silicon Steel and in Aluminum," by G. L. Clark and W. M. Shafer, University of Illinois.

"Notes on the Interpretation of X-Ray Diffraction Diagrams and Evidence of Mosaic Structures," by N. P. Goss, Cold Metal Process Co.

"Effects Upon Furnace Refractories of Protective Gases for High Carbon Steels," by J. H. Loux, Salem Engineering Co.

"Further Notes on Precipitation Hardening in the Heavy Alloys," by W. P. Sykes, General Electric Co.

"Some Properties of Hot Pressed and Sintered Copper Powder Compacts," by C. G. Goetzel, American Electro Metal Corp.

"The Precipitation Reaction in Cold Rolled Phosphor Bronze: Its Effects on Hardness, Conductivity, and Tensile Properties," by R. H. Harrington and R. G. Thompson, General Electric Co.

"The Effect of Impurities on Some High Temperature Properties of Copper," by E. R. Parker, General Electric Co.

Educational Lectures

5:00 P.M.—*"The Strength of Metals Under Combined Stresses,"* by Maxwell Gensamer, Carnegie Institute of Technology.

8:30 P.M.—*"Quenching in Custom Heat Treating,"* by R. G. Roshong, Lindberg Steel Treating Co.

THURSDAY, OCT. 24

"Cementite Stability and Its Relation to Grain Size, Abnormality and Hardenability," by C. R. Austin and M. C. Fetzer, Pennsylvania State College.

"Effect of Deoxidation on Hardenability," by C. V. Cash, T. W. Merrill and R. L. Stephenson, Carnegie-Illinois Steel Corp.

"The Effect of Grain Size on Hardenability," by M. A. Grossmann and R. L. Stephenson, Carnegie-Illinois Steel Corp.

"Hardening Characteristics of Various Shapes," by M. Asimow and M. A. Grossmann, Carnegie-Illinois Steel Corp.

"Effect of Nitrogen on the Case Hardness of Two Alloy Steels," by S. W. Poole, Republic Steel Corp.

"Influence of Silicon and Aluminum Additions on the Constitutional Diagram of 4-6 Cr-Mo Steel, by C. L. Clark, University of Michigan, and M. A. Bredig, Vanadium Corp. of America.

"The Effect of Molybdenum on the Isothermal Transformation of Austenite in Low and Medium Carbon Steels," by J. R. Blanchard, R. M. Parke and A. J. Herzig, Climax Molybdenum Co.

"Effects of Small Amounts of Alloying Elements on the Tempering of Pure Hypereutectoid Steels, by C. R. Austin and B. S. Norris, Pennsylvania State College.

Symposium on Surface Treatment of Metals:

"Anodic Treatment of Aluminum," by J. D. Edwards, Aluminum Co. of America.

"Passivation and Coloring of Stainless Steel," by G. C. Kiefer, Allegheny-Ludlum Steel Corp.

"Chemical Treatment of Magnesium Alloys," by H. W. Schmidt, Dow Chemical Co.

"Corrosion Resistance of Tin Plate; Influence of Steel Case Composition on Service Life of Tin Plate Containers," by R. Hartwell, American Can Co.

"Zinc Coatings: Unit Operations, Costs and Properties," by J. L. Bray, Purdue University, and F. R. Morral, Continental Steel Corp.

"The Fatigue and Bending Properties of Cold Drawn Steel Wire," by H. J. Godfrey, Lehigh University, Fritz Engineering Laboratory.

"The Chafing Fatigue Strength of Some Metals and Alloys," by G. Sachs and P. Stefan, Case School of Applied Science.

"Fatigue and Damping Studies of Aircraft Sheet Materials: Duralumin Alloy 24ST, Alclad 24ST and Several 18-8 Type Stainless Steels," by R. M. Brick and Arthur Phillips, Yale University.

"Alloys of Manganese and Copper: Vibration-Damping Capacity," by R. S. Dean, C. T. Anderson and E. V. Potter, Bureau of Mines, U. S. Dept. of Interior.

Educational Lecture

5:00 P.M.—*"The Strength of Metals Under Combined Stresses,"* by Maxwell Gensamer, Carnegie Institute of Technology.

FRIDAY, OCT. 25

Educational Lecture

9:00 A.M.—*"The Strength of Metals Under Combined Stresses,"* by Maxwell Gensamer, Carnegie Institute of Technology.

Symposium on Surface Treatment of Metals:

"Diffusion Coating on Metals," by F. N. Rhines, Carnegie Institute of Technology.

"Surface Reactions and Diffusion," by J. E. Dorn, J. T. Gier, L. M. K. Boelter and N. F. Ward, University of California.

"Heat Treating with Induction Heat," by Edmund Blasko, Ford Motor Co.

"Inherent Characteristics of Induction Hardening," by M. A. Tran, Park Drop Forge Co., and H. B. Osborn, Ohio Crankshaft Co.

"Flame Pretreatment of Structural Steel Surfaces for Painting," by J. G. Magrath, Air Reduction Sales Co.

"Shot Blasting and Its Effect on Fatigue Life," by F. P. Zimmerli, Barnes Gibson Raymond, Inc.

"Effect of Surface Conditions on Fatigue Properties," by O. J. Horger and H. R. Neifert, Timken Roller Bearing Co.

"Chip Formation, Friction and High Quality Machined Surfaces," by Hans Ernst and M. E. Merchant, Cincinnati Milling Machine Co.

"Observations on the Tarnishing of Stainless Steels on Heating in Vacuo," by V. C. F. Holm, National Bureau of Standards.

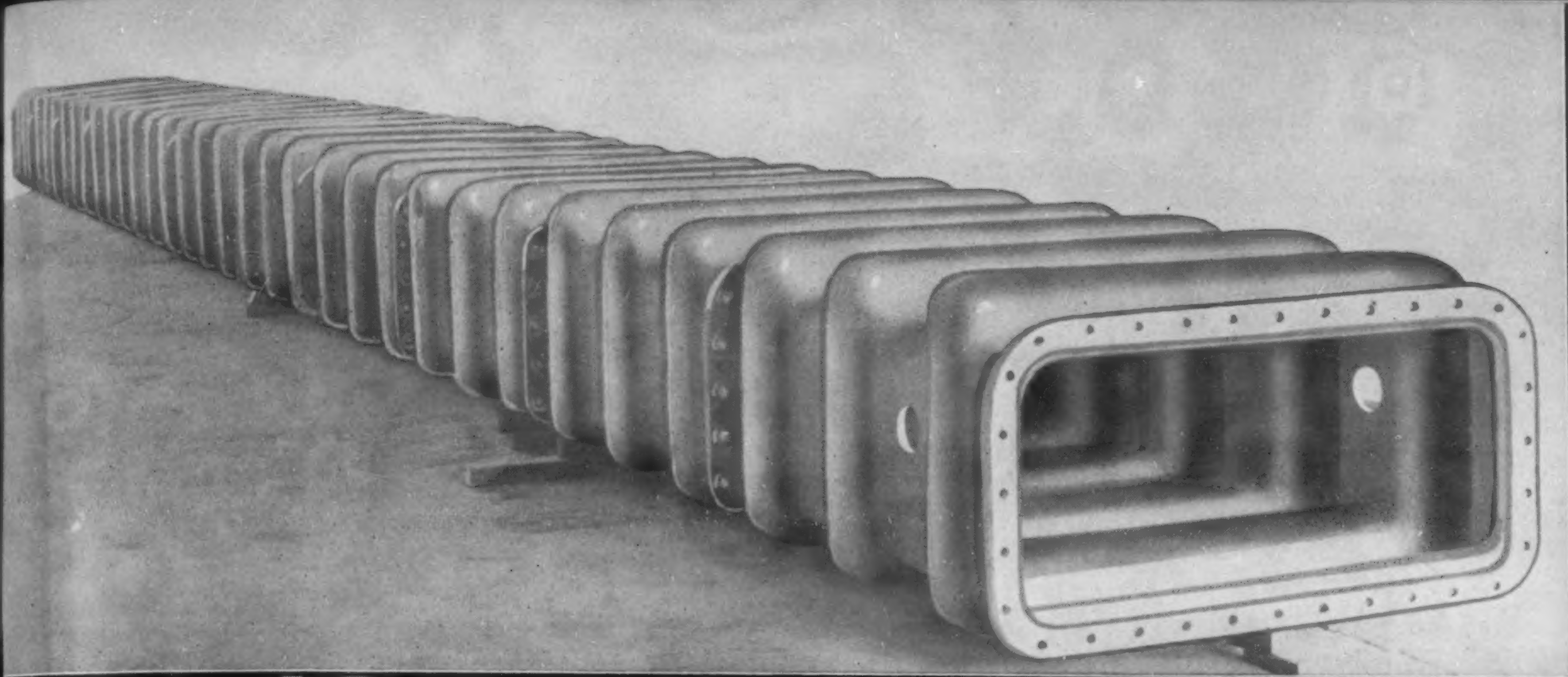
"The Tracer Method of Measuring Surface Irregularities," by E. J. Abbott, Physicists Research Co.

The following papers will be presented by title:

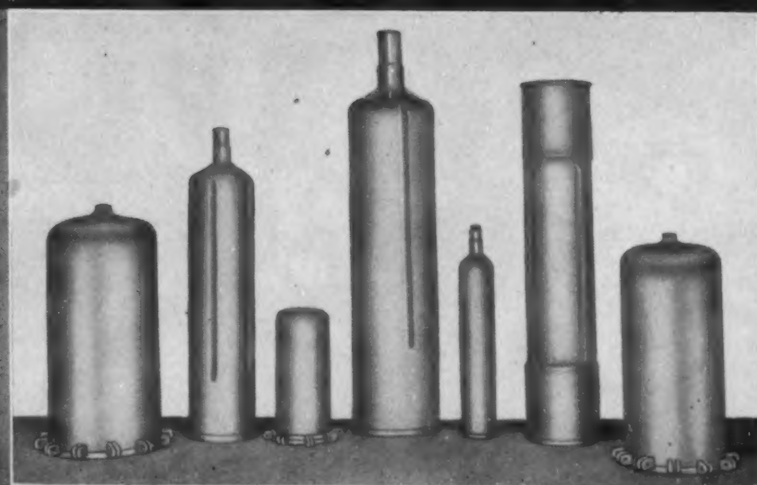
"Alloys of Manganese and Copper: Electrical Resistance," by R. S. Dean and C. T. Anderson, Bureau of Mines, U. S. Dept. of Interior.

"The Alloys of Manganese and Copper: Hardening by Cold Work and Heat Treatment," by R. S. Dean and C. T. Anderson, Bureau of Mines, U. S. Dept. of Interior.

"The Alloys of Manganese-Copper and Nickel: Hardening in the Pseudo Binary System Cu-Mn-Ni," by R. S. Dean and C. T. Anderson, Bureau of Mines, U. S. Dept. of Interior.



castings since 1919



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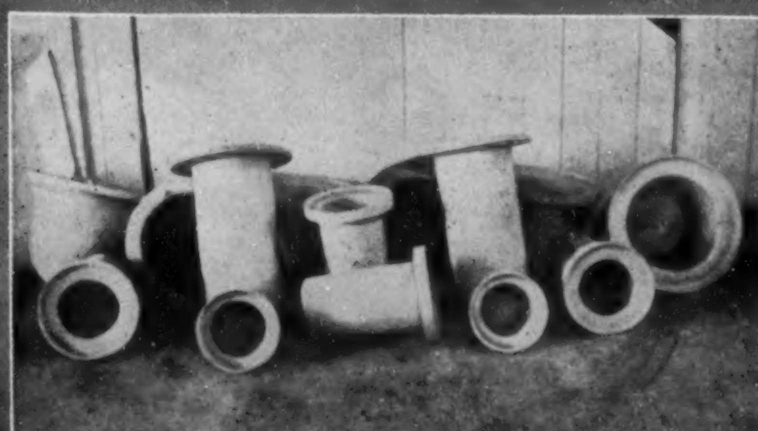
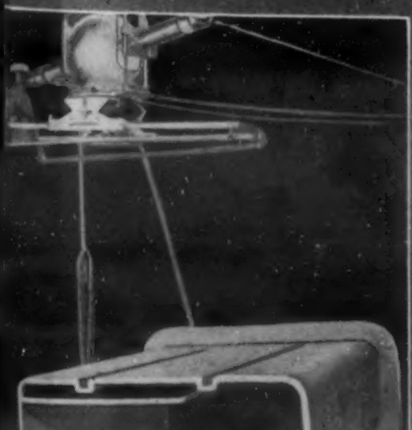
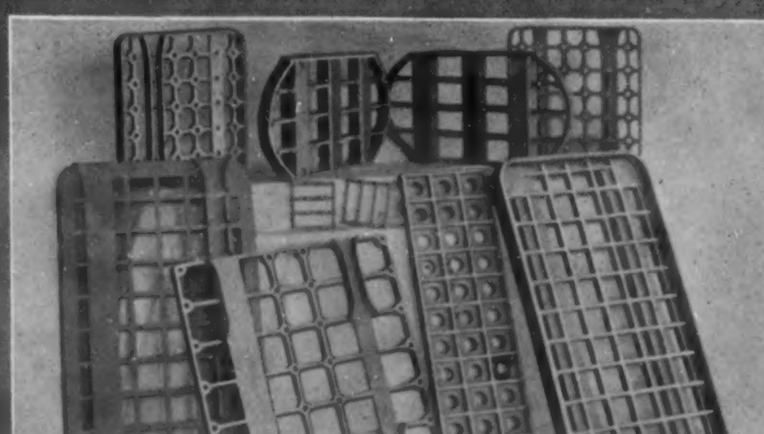
BOOTH G-2 NATIONAL METAL EXPOSITION







THERMALLOY the "EYE" of QUALITY

QUALITY CASTINGS SINCE 1919

THE ELECTRO ALLOYS COMPANY

CASTINGS FOR HEAT CORROSION

ELYRIA, OHIO

Technical Program of the

Metal Divisions of the A. I. M. E.

F. T. Sisco
Chairman
Iron and Steel
Division

E. M. Wise
Chairman
Institute of Metals
Division

THE USUAL EXCELLENT technical program of some 15 papers has been prepared for the sessions of the Iron and Steel and the Institute of Metals Divisions of the American Institute of Mining and Metallurgical Engineers. The headquarters are at the Hotel Cleveland, where all sessions will be held. These commence on Monday, Oct. 21, and end on Wednesday, Oct. 23.

The annual autumn joint dinner of the two divisions is scheduled for Tuesday evening, Oct. 22. The principal after-dinner speaker, to be announced, is expected to discuss the "Role of the Metallurgist in the National Defense Program."

The tentative technical program follows:

MONDAY, OCT. 21

INSTITUTE OF METALS AND IRON AND STEEL DIVISIONS—JOINT SESSION ON CONSTITUTION OF ALLOYS:

"An Investigation on the Structure and Properties of Some Iron-Nickel Alloys," by George Sachs and J. Spretnak, Case School of Applied Science.

"Precision X-Ray Study of the High Silver Aluminum-Silver Alloys," by Frank Foote, Cooper Union, and Eric R. Jette, School of Mines, Columbia University.

"X-Ray Analysis of Hot-Galvanized Heat-Treated Coatings," by F. R. Morral, Continental Steel Corp., and E. P. Miller, Purdue University.

IRON AND STEEL DIVISION—BESSEMER STEEL:

"The Acid Bessemer Process of 1940," by H. W. Graham, Jones and Laughlin Steel Corp.

"Method of Dephosphorization of Bessemer Steel," by B. P. Hazeltine, Wheeling Steel Corp.

INSTITUTE OF METALS DIVISION—LEAD AND ZINC:

"Creep and Recrystallization of Lead," by Albert A. Smith, Jr., American Smelting and Refining Co.

"Tensile Properties of Rolled Magnesium Alloys: Binary Alloys with Calcium, Cerium, Gallium and Thorium," by John C. McDonald, Dow Chemical Co.

"X-Ray Study of the Solid Solutions of Lead, Bismuth and Gold in Magnesium," by Frank Foote, Cooper Union and Eric R. Jette, Columbia University.

"The Grain Orientation of Cast Polycrystalline Zinc, Cadmium and Magnesium," by Gerald Edmunds, The New Jersey Zinc Co.

TUESDAY, OCT. 22

INSTITUTE OF METALS DIVISION—COPPER:

"Coalesced Copper; Its History, Production and Characteristics," by H. H. Stout, Consulting Metallurgical Engineer.

"The Hydrogen Embrittlement of Pure Copper," by Frederick N. Rhines and William A. Anderson, Carnegie Institute of Technology.

"The Effect of Composition upon Physical and Chemical Properties of 14-K Gold Alloys," by Tracy C. Jarrett, American Optical Co.

IRON AND STEEL DIVISION—SURFACE QUALITIES:

"Surface Finish and Structure," by John Wulff, Massachusetts Institute of Technology.

"Analysis of the Cold-Rolling Texture of Iron," by Charles S. Barrett and L. H. Levenson, Carnegie Institute of Technology.

INSTITUTE OF METALS AND IRON AND STEEL DIVISIONS—JOINT SESSION ON PHYSICAL METALLURGY:

"Measurement of Irreversible Potentials as a Metallurgical Research Tool," by R. H. Brown, William L. Fink and M. S. Hunter, Aluminum Co. of America.

"On the Solidification of Solid Solutions Under Equilibrium Conditions," by Morris Cohen, Massachusetts Institute of Technology, and William P. Kimball, Thayer School of Civil Engineering, Dartmouth College.

WEDNESDAY, OCT. 23

INSTITUTE OF METALS AND IRON AND STEEL DIVISIONS—JOINT SESSION:

"Electrolytic Polishing of Metals—Metallographic and Commercial"; Round Table Discussion.

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Technical Program of the

American Welding Society

AT ITS ANNUAL CONVENTION during the National Metal Congress, the American Welding Society, at some 15 different sessions, will present a program of some 55 technical papers. The sessions are scheduled for each day of the 5-day Congress, many of them simultaneous, and embracing various subjects related to welding activities. The Hotel Cleveland is the society's headquarters where all technical sessions will be held.

This year, at the annual banquet, to be held at the headquarters, Thursday evening, Oct. 24, there will, for the first time, be no speakers—it will be presided over by the society's president, George T. Horton, and the evening will be devoted to entertainment and dancing.

The technical papers scheduled follow:

MONDAY, OCT. 21

SHIPBUILDING AND STRUCTURAL SESSION

"Welding in Shipbuilding," by David Arnott, American Bureau of Shipping.

"Welded Rigid Frame Structures," by A. Amirikian, Navy Department.

STEEL MILL SESSION

"Resistance Flash Welding of Strip in Steel Mills," by J. H. Cooper, Taylor Winfield Corp.

"Design and Fabrication of Heavy Rolling Mill Machinery," by G. W. Linkhauer, United Engineering & Foundry Co.

"Shape Cutting in Steel Mill," by Joseph Stanley, Carnegie-Illinois Steel Corp.

"Hard Facing Steel Equipment," by Frank L. Gray, Carnegie-Illinois Steel Corp.

INDUSTRIAL RESEARCH SESSION

"Flexible Beam Connections," by Bruce Johnston and L. F. Green, Lehigh University.

"Weldability of Carbon Steels," by C. E. Jackson and G. G. Luther, Naval Research Laboratory, Anocostia Station.

"Defects in Weld Metal and Hydrogen in Steel," by Carl A. Zapffe and C. E. Sims, Battelle Memorial Institute.

TUESDAY, OCT. 22

MACHINERY SESSION

"Welding and Cutting Problems in Small Fabricating Shop," by Roger B. White and J. T. Lewis, Lewis Welding & Eng.

"Welding Electrical Machinery," by R. A. Taylor, Westinghouse Electric & Mfg. Co.

"Recent Developments in Flame Machining," by H. E. Landis, Jr., and J. G. Magrath, Air Reduction Sales Co.

FUNDAMENTAL RESEARCH SESSION

"A Method of Studying the Effects of Inertia and Friction in Resistance Welding Machines," by W. F. Hess and R. A. Wyant, Rensselaer Polytechnic Institute.

"The Welding of Carbon-Molybdenum Piping for High Temperature High Pressure Service," by R. W. Emerson, Pittsburgh Piping & Equipment Co.

"Microfissuring in Multi-Pass Welds," by J. L. Miller and L. R. Kovac, Armour Institute of Technology.

TUESDAY, OCT. 22

MACHINERY SESSION

"Flame Hardening," by R. H. Zielman, Thew Shovel Co.

"Production Flame Hardening of Machine Parts," by John Erler and P. H. Tomlinson, Farrel-Birmingham Co., Inc.

"High-Speed Mechanized Oxy-Acetylene Welding," by H. T. Herbst, The Linde Air Products Co.

"Machine Flame Cutting in Preparation for Welding," by W. Roy Widdoes, By-Products Steel Corp.

"Use of Welding and Cutting in the Fabrication of Ditching Equipment," by A. R. Askue, Cleveland Trencher Co.

FUNDAMENTAL RESEARCH SESSION

"Welded Girders With Inclined Stiffeners," by Cyril Jensen and C. Antoni, Lehigh University.

"Determination of Contact Resistance," by W. B. Kouwenhoven and J. Tampico, Johns Hopkins University.

"Electrodes for Welding Cast Iron," by G. S. Schaller, University of Washington.

"Fundamentals of Resistance Welding," by R. S. Pelton, General Electric Co.

WEDNESDAY, OCT. 23

RESISTANCE WELDING SESSION

"Resistance Welding Electrodes—Some Fundamental Considerations," by G. N. Sieger, S-M-S Corp.

"Changes in the Shape of Spherical Spot-Welding Electrodes," by W. F. Hess and R. A. Wyant, Rensselaer Polytechnic Institute.

"Recorders and Indicators for Resistance Welding Machines," by W. C. Hutchins, General Electric Co.

COMBINED FUNDAMENTAL-INDUSTRIAL RESEARCH SESSION

"The Effect of the Physical State of Steel Upon the Tensile Strength of Brazed Joints," by F. C. Kelley, General Electric Co.

"Causes of Crater Formation," by G. E. Doan, Lehigh University.

"Improving Ductility of Oxy-Acetylene Welds by Aging," by J. R. Dawson and A. R. Lytle, Union Carbide & Carbon Research Laboratories.

"Cold Rolling Testing of Welded Joints," by T. P. Hughes and R. L. Dowdell, University of Minnesota.

RESISTANCE WELDING SESSION

"Scope and Limitations of the Stored Energy Type Resistance Welding," by C. Weygandt, Moore School of Engineering, University of Pennsylvania, and G. S. Mikhalapov, Baldwin-Southwark Div., Baldwin Locomotive Works.

"A Study of Spot Welding on a Copper Base Alloy," by M. L. Wood, J. Babin and O. B. Atkin, Chase Brass & Copper Co.

"Stored Energy Systems of Spot Welding," by H. B. Axtell and R. L. Ringer, Jr., Taylor-Winfield Corp.

"Resistance Brazing in Electrical Apparatus Manufacture," by R. J. Wensley, I-T-E Circuit Breaker Co.

"Spot Welding in Aircraft Construction," by C. F. Marschner, McDonnell Aircraft Corp.

(Continued on page 514)

GEORGE T. HORTON
PRESIDENT

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Long before the present emergency, plants all over the country, interested in metal joining found that Sil-Fos and Easy-Flo provided reliable joints in fast time at low cost. Large quantities are now regularly used in the automotive, aviation, electrical, refrigeration, air-conditioning and coppersmithing industries and for general manufacturing. These alloys are included in Navy and Federal Specifications. To manufacturers now interested in faster production without sacrificing reliability, Sil-Fos and Easy-Flo offer an opportunity that is well worth investigating.
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NAME
TITLE
COMPANY
STREET
CITY & STATE

Technical Program of the

Wire Association

A PROGRAM OF ABOUT 15 technical papers will be presented before the annual meeting of the Wire Association. They will include discussions in both the ferrous and non-ferrous divisions of the society, and will commence on Monday, Oct. 21 and extend through Thursday, Oct. 24. Some new motion pictures will be a feature.

The headquarters of the society will be the Hotel Carter where the technical sessions will be held. The annual banquet is set for Wednesday evening, Oct. 23.

The technical program is tentatively as follows:

"What Does Good Laboratory Practice Do to Help Production in the Steel Industry," by George P. Lenz, Union Drawn Steel Division, Republic Steel Corp.

"Application of Tungsten Carbide Tools and Dies," by Firth-Sterling Steel Co.; Motion Picture.

"Electro Chemical Applications in the Wire Industry," by C. L. Mantell, New York City.

"Copper From Mine to Market," by Phelps Dodge Copper Products Co.; Motion Picture.

"Uses of Lime in the Wire Industry," by D. E. Washburn, The Warner Co.

"The Use of Plane Polarized Light and Sensitive Tint Illumination in the Analysis of the Microstructure of Steel," by B. L. McCarthy, Wickwire Spencer Steel Co.; Mordica Memorial Lecture.

"Tungsten Carbide Dies and Tools," by James R. Longwell, Carboloy Co.

"Recent Developments in Heating Copper Wire Bars," by John A. Doyle, W. S. Rockwell Co.

"Continuous Annealing," by C. B. Fantone, Syncro Machine Co.

"The Endurance Properties of Hard Drawn Wire From Various Kinds of Copper," by John N. Kenyon, Columbia University.

"Reactive Drawing Results," by H. A. Stringfellow, Worcester, Mass.

"Galvanizing Characteristics of Different Types of Steels," by Robert W. Sandelin, Atlantic Steel Co.

"Design and Operation of a New Copper Wire Drawing Plant," by H. Blount, Point Breeze Works, and J. D. Wiltrakis, Kearny Works, Western Electric Co.

"Development of Apparatus for Shaving Copper Wire Commercially," by C. E. Weaver, General Electric Co.

(A. W. S. Program continued from page 510)

STRUCTURAL SESSION

"Shall We Weld Our Bridges?" by Fred L. Plummer, Hammond Iron Works.

"Design and Construction of Arc Welded Steel Structures," by LaMotte Grover, Air Reduction Sales Co.

"Flame Cleaning of Structural Steel," by F. H. Dill, American Bridge Co.

THURSDAY, OCT. 24

PIPE WELDING SESSION

"Pipe Welding for the Naval Service," by Bela Ronay, U. S. Naval Engineering Experiment Station.

"Welding of Copper and Red Brass," by J. J. Vreeland and J. Babin, Chase Brass & Copper Co.

"Investigation of Gas and Arc Fillet Welds in Piping," by Eric Seabloom and I. H. Carlson, Crane Co.

"Preheating—Welding—Normalizing," by C. J. Holslag, Electric Arc Cutting & Welding Co.

PROCEDURE CONTROLS AND SPECIAL APPLICATIONS

"Cost and Procedure Control by Use of Polarized Light," by E. W. P. Smith, Lincoln Electric Co.

"Training of Operators for Welding," by S. Lewis Land, Supervisor of Industrial Education, N. Y. State Dept. of Education.

"Codes for Welded Pressure Vessels," by D. S. Jacobus, Babcock & Wilcox Co.

"Aircraft Welding," by Hanford Eckman, Piper Aircraft Corp.

"Design and Construction of Large Cement Kilns," by C. A. Malmberg, Allis-Chalmers Mfg. Co.

FRIDAY, OCT. 25

METALLURGICAL SESSION

"Properties of 18-8 Weld Deposits," by K. W. Ostrom, Arcos Corp.

"Metallurgical Changes at Welded Joints, and the Weldability of Steels," by R. H. Aborn, U. S. Steel Corp. Research Laboratories.

"Silver and Alloy Soldering," by C. Zappone, Robertshaw Thermostat Co.

RAILROAD SESSION

"Welding in Tank Car Construction," by J. W. Sheffer, American Car & Foundry Co.

"Welding of Passenger Cars," by A. M. Unger, Pullman-Standard Car Mfg. Co.

Metallurgical Engineering Digest

FERROUS AND NON-FERROUS

1. Production

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die-Castings.

2. Processing and Fabrication

Drop and Hammer Forging, Drawing, Extruding, Stamping and Machining. Age-Hardening, Annealing, Carburizing, Hardening, Malleableizing, Nitriding, Surface-Hardening and Tempering. Heating Furnaces, Refractories, Fuels and Auxiliaries. Welding, Flame-Cutting, Hard-facing, Brazing, Soldering and Riveting. Cleaning, Pickling, Electroplating, Galvanizing, Metallizing, Coloring and Non-Metallic Finishing.

3. Properties and Applications

Physical and Mechanical Properties (including Fatigue and Creep). Corrosion and Wear. Engineering Design of Metal-incorporating Products. Selection of Metals and of Metal-Forms. Competition of Metals with Non-Metals. Specific Applications of Metals and Alloys.

4. Testing and Control

Physical and Mechanical Property Testing and Inspection. Routine Control and Instrumentation. X-ray and Magnetic Inspection. Spectrographic and Photoelastic Analysis. Corrosion- and Wear-Testing. Examination of Coatings. Surface Measurements. Metallographic Structure and Constitution.

5. General

Articles pertinent to more than one of the previous sections.

1 Production

OF METALS, MILL PRODUCTS, CASTINGS

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die Castings.

1a. Ferrous

Rolling Steel Sheet

A Composite

Two good, practical reviews of some of the melting and rolling factors that affect the quality of steel sheet have been published in recent issues of *Sheet Metal Industries.*

According to T. GREY-DAVIES, most defects originate in the steel-making or casting process as seams, broken surface, scabs, blisters, or dirty steel. Rimmed steel ingots sometimes have blowholes close to the surface and the thin skin may break through during processing. Some ingot cracks are also associated with the type of blowholes present.

Some defects, such as blisters, may be seriously aggravated in further processing, *i.e.* by incorrect pickling or heating. Streaks are usually caused by clay or ganister inclusions from the open hearth department, but may also be caused by lack of cleanliness in the rolling department. Stickers are usually caused by incorrect temperature and pressure in processing, although it is known that high phosphorus steels are less liable to this defect than low-phosphorus. Roll marks, uneven gage, and rough corners are some of the defects attributable only to the rolling mill.

The fundamental requirements for good gage in cold rolling are examined by F. MOHLER ("Ten Essentials for Accurate Rolling Practice", *Ibid.,* Aug. 1940, pp. 833-836.) Good quality hot strip is, of course, vital and large coils are essential. Operating and control equipment should include: Shunt wound motors so designed that a maximum of 40% current is not exceeded in accelerating to maximum speed in 10 sec.; tensiometers for indicating the tension; vernier rheostats for adjusting the speed and tension between stands; and tapered tension control for obtaining increased tension between stands at the threading speed and gradually tapering it to the running value as the mill is accelerated to running speed.

Other aids to quality are the use of an automatic gage control system following the second and last stands, and screwdown follow-up control for the first stand and the last stand if rolling practice requires the raising of screws at the end of each coil.

JZB (1a)

Contraction in Gray Iron

"SOME OBSERVATIONS ON CONTRACTION IN GREY CAST IRON." E. LONGDEN. *Foundry Trade J.,* Vol. 62, June 13, 1940, pp. 432-434, 438. Original research.

Little attention has been paid to the effect of volume changes on large commercial castings. Arrests in the contraction rate, or an expansion at critical temperatures, are generally quite pronounced, and seem to be traceable to the large amount of carbon present in cast iron, and its condition. The precipitation of primary graphite on solidification, and secondary graphite at lower critical temperatures, will account for expansions.

According to Turner, phosphorus is responsible for an expansion if present in appreciable quantities. Generally speaking, there are 2 distinct arrests in low-phosphorus irons, and 3 in high. The final amount of contraction will be influenced by the ratio of free carbon to combined carbon in the completely-cooled casting. The data presented in this paper, however, indicate that final contraction and the absence or presence of stresses in many types of castings are due also to simultaneously opposing expansion and contraction influences in the same casting. In long castings, mold and core resistance will reduce contraction and induce stresses.

A method was devised for ascertaining the behavior of large castings during cooling from the point of solidification to atmospheric temperature. The movement of the casting is followed by frequent measurements between fixed points outside the mold and rods held by the metal of the casting. Where feasible, temperature readings are correlated with volume changes.

Tests made on castings up to 47 ft. long showed that thick sections contract more than thin in castings where thick and thin sections are linked in such proximity as to be affected by mutual influences. If, however, the same contrasting sections are cast as simple, uniform and separate units, contraction follows expectations—that a thin

section of gray iron will contract more than a thicker section of the same analysis because of the more rapid freezing of the lighter section and the effect of this more rapid cooling on the grain size and graphite formation.

A probable explanation is that, in the case of a one-piece casting the thin sections during freezing and cooling are subjected to an extensional stress created by the resistance of the thicker sections, which are not ready to contract. The frictional resistance of the mold and cores, and the expansion of cores on being heated up by the molten metal, will also tend to subject the cooling metal to extensional stress.

Again, a study of the very clear arrest and expansion periods noted on the cooling curves (especially for the heavy and large boring bars) indicates that a thick section may be undergoing an expansion at a time that a thinner section has passed its expansion period and is contracting. Under these conditions the thin section will suffer extensional stress. Conversely, the thicker sections will be subjected to a compressional stress by the effort of the earlier cooled members to contract. Finally, the heavy sections on cooling assume a shorter length by bending certain sections of the casting, or by fracture in the weakened or most highly stressed sections. AIK (1a)

Molding Sand for Cast Iron

A Composite

The need for systematic and intelligent sand testing and control as an adjunct to the production of high quality gray and malleable iron castings is forcefully demonstrated by a group of papers presented at the recent annual meeting of the American Foundrymen's Assoc. The effect of sand quality and practice on the properties of the finished iron is so direct as to be susceptible of classification.

Thus H. W. Dietert & E. E. Woodliff ("Sand Affects Physical Properties of Gray Iron," *Amer. Foundrymen's Assoc.*, 1940, Preprint No. 40-9) studied the effects of moisture and permeability on various properties of a gray iron. They found that fluidity, feeding, transverse strength and deflection value of the iron are reduced with excess moisture in the sand. At the same time fracture is finer, graphite is refined, steadite areas are reduced in size, ferrite areas are increased in size, and porosity and chill are increased.

With increased permeability, fluidity is reduced, fracture is finer and of lighter color, graphite is refined, and the size of steadite areas is reduced. The pearlite areas are more completely developed in low-permeability sands and less completely developed, with larger areas of ferrite, with high permeability. Moisture has a greater influence on the properties of the gray iron than permeability, although the latter does exert a noticeable effect.

A progress report of some work on synthetic sand mixtures for gray iron castings is presented by Fulton Holtby & H. F. Scobie ("Recent Experiments with Gray Iron Synthetic Molding Sands," *Ibid.*, Preprint No. 40-11). So-called "steel sand fines," which include the sand and other materials removed from the sand used in a steel foundry, can be used as low-permeability blending sand to control the properties of gray iron molding sands of similar composition.

Casting properties, particularly shrinkage and piping, are correlated with mold hardness, green compressive strength, permeability, moisture and sea coal by H. L. Womochel & C. C. Sigerfoos ("Influence of the Mold on Shrinkage in Ferrous Castings," *Ibid.*, Preprint No. 40-28) in another progress report. Piping tendencies, internal shrinks and sinking of the cope face may be traced to dimensional changes in the mold cavity. High moisture, high green compressive strength, soft ramming and unfavorable grain distribution of the sand tend to promote shrinkage defects in gray iron.

Sea coal decreases the amount of piping in gray iron poured in green sand. Small gray iron castings made in baked core sand molds show no shrinkage defects. Steel castings, it is noted, are less susceptible to influence of the mold than are gray iron castings.

The old customs of one malleable foundry using natural bonded sands were transformed only with the greatest difficulty to something approaching quality operation, reports D. F. Sawtelle ("A Sand Control Program in a Malleable Foundry," *Ibid.*, Preprint No. 40-23) in an interesting case history. The feat was finally accomplished after sand testing plainly showed the true picture of sand conditions. The paper is recommended to all foundrymen who still doubt that the installation of sand testing equipment can help them to solve many of their problems. CMS (1a)

Gas in Liquid Iron

"Gas in Liquid Cast Iron." Wm. Y. Buchanan. *Foundry Trade J.*, Vol. 62, June 13, 1940, pp. 439-442, 448. Original research.

The determination of the gas content of liquid cast iron is a difficult matter, yet one that is very important from the standpoint of practice. This was well brought out in an earlier article by this author (see "Gases and Metals", Metals and Alloys, Vol. 11, Mar. 1940, p. MA 164).

To avoid evolution of steam and gases from the sample ladle of liquid iron, it was found necessary to bore holes in its shell before putting in the refractory lining and drying. The use of a lining wash must be avoided. A modification of gas analysis burette was found necessary to accommodate the rapid evolution of gas from the molten sample. One rapid increase in gas volume occurs near solidification, possibly due to the separation of primary graphite.

Thermocouples are perhaps the best means of reading temperature changes, although the optical pyrometer is easier to handle. A gas analysis apparatus capable of analyzing small volumes (10 ml.) is required and a suitable design is illustrated and described in detail. A number of data on lbs. of water per hr. chargeable to atmospheric moisture in the air blast and notes and references on methods and results of dry blast are given.

A series of tests on gas volume and composition with normal changes in atmospheric conditions led to the conclusion that normal variations of furnace condition throughout the blow have more influence on the gas composition than does the moisture content of the blast itself. Also, there is no definite relationship shown between the total volume or maximum rate of evolution of gas from liquid cast iron and the moisture of the blast.

In spite of these conclusions it was felt advisable to introduce water directly into the blast. This test showed an increase in hydrogen content due to introduction of the water and an increase in the rate of evolution of from 32 ml./min. before water introduction to 90 ml. with water introduced. Similar results were found on another cupola.

The addition of 4% of steel turnings to liquid cast iron causes an insignificant temperature drop and effects a definite reduction in gas content. Tests were undertaken to determine the effects of dissolved gases on foundry shrinkage cavities or localized porosity. These indicated that the tendency toward foundry shrinkage cavities is not increased by degasification. Also, dissolved gas does not in any way influence porosity in foundry shrinkage defects.

The actual composition of gases evolved from liquid cast iron varies over a wide range, as shown by the following table:

CO_2—nil to 5.2%
O_2—0.1 to 0.9
CO—5.7 to 23.1
H_2—6.7 to 20.0
N_2—59.2 to 80.1
CH_4—nil to 2.3

[*In view of recent American work on the influence of gases on graphitization, the findings of Buchanan on gases in liquid irons are highly suggestive. Direct correlations have not been sought by investigators, and the need for such research is implied.*—J.W.B.] AIK + JWB (1a)

Forging Tool Steel

"How to Forge Tool Steel." Adam M. Steever (Columbia Tool Steel Co.) *Iron Age*, Vol. 146, July 25, 1940, pp. 21-27. Practical.

The mechanical working involved in forging tool steels is essential to break up the large crystals of the ingot, refine the casting structure and produce proper grain size and homogeneity. Forging causes plastic flow in the heated metal but during the operation the metal is continually cooling and this retards its ability to flow—hence the time available for the operation is definitely limited.

The principle of the forging hammer is that of an instantaneous application of force to a small area governed by the size of the dies and the section of the metal being forged. The increased density of the metal due to working and its friction against the dies retard its ability to flow. Strains set up in the metal are compressive and are directed chiefly vertically below the hammered area; a small portion of the blow is transmitted in horizontal directions. The suddenness of the blow tends to localize refinement of structure to the exterior, but if the work is rotated between blows, metal flow is continuous and almost entirely in a longitudinal direction.

In forging tool steel there are 4 principal steps—heating for forging, ingot cogging, surface conditioning of the billet, and finish-forging. The heating method and conditions are critical.

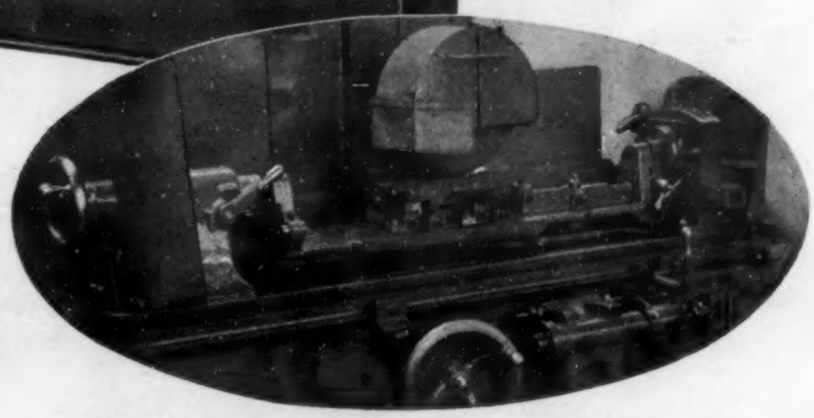
Generally speaking, heating rate has been much too slow. The use of gas for fuel and positive pressure blowers with full pyrometer control have aided in the production of more uniform and better-surfaced material at much higher speeds than formerly. Overshooting of maximum temperatures, especially with incorrect atmospheres, can result in overheated or "burned" steel. Time at maximum temperature should be limited chiefly to avoid surface decomposition.

Because of their high carbon content, tool steels are subject to rapid decarburization at the high temperatures used for forging. To lessen this condition, ingots, bars or billets are preheated before charging into the forging furnace. The atmosphere in the latter is also of great importance, and should be slightly oxidizing; an atmosphere

SAVE

"a mile a minute"

New Morgan Guide Grinder



The upper photographs show the operator making adjustments for grinding a twist guide, also details of cradle mounting with splash guard removed. Below is shown a view from the rear of the machine.

A mile of grooved section is too high a price to pay for "working in" a set of guides. Yet until now, there has been no single machine on which guides of all styles and sizes could be accurately ground.

The Morgan Construction Company has developed a new Guide Grinder to meet every requirement of this important job. It will handle guides of all types and sizes required in a rod mill. Its manual and automatic controls provide for every adjustment—up, down, backward, forward, for straight or twist guides. It is compact and self-contained—can be set anywhere.

Here is an investment in equipment that will be worth miles of rod saved to you, in improved quality of finished section.

MORGAN CONSTRUCTION COMPANY
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R62

LET MORGAN WORCESTER ENGINEERS AND MANUFACTURERS REMOVE THE LAGS

containing 11% carbon dioxide and 1% oxygen is recommended.

High speed steels, tungsten hot-work steels, high-carbon high-chromium steels, etc.—all of a segregated, coarse columnar ingot structure—are hammer-cogged as soon as cast. Stripped from the molds at about 1700° F. the tapered ingots are immediately charged into a reheating furnace at the same temperature, then given a series of light hammer blows while moved in short steps over the dies. Reheating and more severe hammering are continued until the right cross-section is reached. Corner cracks are removed with a gouge.

For carbon and low alloy steels no special care in cogging is required. These can be charged into a preheating furnace at 1400° F., soaked, then (in the same furnace) heated to forging temperature in 400° F. steps, with about 1 hr. at forging temperature. Some high-alloy types must be annealed in billet form to avoid grinding cracks. VSP (1a)

1b. Non-Ferrous

Bronze and Red Brass Castings

"Melting and Pouring Sand Cast Bronzes, Red and Semi-Red Brasses. Tentative Recommended Practice of the Non-Ferrous Division of A. F. A." *Can. Metals & Met. Inds.*, Vol. 3, Aug. 1940, pp. 206-207. Report.

In general, the metal should be melted as rapidly as possible, since the absorption of gas by the metal and the oxidation of the metal are both a function of time and temperature. The harmful effects of gas absorption may be corrected by allowing the metal to solidify and remelting under correct furnace conditions, as the gas absorbed during melting tends to be liberated upon solidification of the metal. A slightly oxidizing flame or furnace atmosphere is desirable.

In crucible melting, the use of oil and gas facilitates faster melting and better control over melting conditions. A charcoal covering is recommended when natural draft is used. A flux of the glass type is helpful in collecting the drosses if the metal is dirty or a large percentage of borings is used. The flux is used when forced draft is employed. If a certain percentage of foundry scrap is used in the melt, it should be charged into the furnace first. Zinc should be added to replace that burnt out during melting.

For deoxidation an alloy of copper with 10-15% P is generally used. Normally 1 oz. of 15% phosphor-copper per 100 lbs. of metal is sufficient. Additions of deoxidizers are best made in the ladle or crucible after any slag or dross has been skimmed off; the metal should then be stirred well. The best pouring temperature for these alloys is closer to the high limit than to the low limit of the range that gives sound castings. WHB (1b)

Producing Aluminum Alloy Wire

"The Rolling and Drawing of Wire from Alloys of the 24S Type." A. T. Bundin. *Aluminium & Non-Ferrous Rev.*, Vol. 5, Mar. 1940, pp. 21-26 (to be cont'd.); translated from *Metallurg*, No. 2, 1939, pp. 98-109. Original research.

In manufacturing the 24ST alloy (4.4% Cu, 1.5 Mg, 0.6 Mn, remainder aluminum) a melting temperature of 1400°-1420° F. was used. This was maintained for 60-90 min., and the magnesium was added after removal of the crucible. Powdered zinc chloride ($ZnCl_2$) was used for refining. The alloy was poured at 1275°-1325° F. into cast iron molds inclined, at the start, at an angle of 70-80°.

The alloy was extruded at 720°-790° F. A splitting at the ends was observed quite frequently on extruding and rolling. An homogenizing treatment at 915°-930° F. was applied for 10-20 hrs. in some cases. The extruded bars were hot rolled, but the deformation applied (41%) was too severe for the 24S alloy (regular Duralumin could be rolled in this manner). A mill was used, therefore, that provided less rigorous deformations—a reduction from 3.35 in. diam. to 1.5 in. square in 18 passes. This was followed by a finishing rod mill, finishing the rod to 0.283 in. diam. in 11 passes.

Although this method was satisfactory, it was not very economical, and an alternative method was used, consisting of extruding to smaller diameters (1.8-2.0 in.) and then rolling down in 14-17 passes. There, too, the output was low, so a third schedule comprising extrusion to 1.8-2.0 in., heat treatment, and rolling to 0.28 in. in a rod mill was investigated. The best temperature for rod mill operation was 660°-720° F. In the finishing passes the high deformation at great speed creates heat which compensates for heat losses.

Before wire drawing, an annealing treatment at 660° F. should be applied, preferably in an electric convected-air furnace. A duplex anneal at 800° F. for 4 hrs. and 500° F. for 3 more hrs. yielded better elongation values (up to 14.3%). An oil-fired furnace was also successfully used. Some aging was noticeable after 62 hrs. RPS (1b)

Processing 2 and Fabrication

FORGING, FORMING, MACHINING HEAT TREATMENT, WELDING, FINISHING

Drop and Hammer Forging, Drawing, Extruding, Stamping and Machining. Age-Hardening, Annealing, Carburizing, Hardening, Malleableizing, Nitriding, Surface-Hardening and Tempering. Heating Furnaces, Refractories, Fuels and Auxiliaries. Welding, Flame-Cutting, Hardfacing, Brazing, Soldering and Riveting. Cleaning, Pickling, Electroplating, Galvanizing, Metallizing, Coloring and Non-Metallic Finishing.

Carbide Cutting Tools

A Composite

The increased use of cemented carbide cutting tools as a likely method of enlarging our effective machine-tool capacity in the face of defense program requirements has been discussed in previous issues of this magazine (August, p. 175: September, p. 304). Such an extension of application can be of major significance in the first place only by virtue of the development in recent years of cemented tungsten carbide mixtures capable of cutting steels. This extension of applicability beyond the field of the softer materials—cast iron, brass, bronze, etc.—has made the carbide tool materials available for "general-purpose" machining and thereby of maximum value to general armament and machinery production.

Thus, Warner & Swasey Co. and the Bullard Co. (among others) successfully employ standard carbide tools as general-purpose tools throughout their plants, reports W. G. ROBBINS of Carboloy Co. ("Cemented Carbides", *Tool Engr.*, Vol. 9, July 1940, pp. 16-18, 20, 22, 52) in an interesting contribution to a symposium on cutting tool materials. General-purpose application in these cases stems from the use of standard tools ground to fit the job. The one-time impracticability of regrinding carbide tools no longer exists, and they can now be reground to a given shape from existing standards in the same way as are stellite or high speed steel tools.

Steel-Cutting Carbides

The steel-cutting carbides are, generally speaking, tungsten carbides with which have been mixed selected amounts of tantalum carbide or titanium carbide to achieve characteristics not provided by straight tungsten carbide. [*The manufacturer of "Kennametal", a recently-developed steel-cutting carbide tool material, claims that his basic material is actually the compound tungsten-titanium carbide* ($WTiC_2$) *rather than a mixture of carbides, and that it has a characteristic crystallography and a higher hardness than carbide mixtures.—F.P.P.*] The trend in the carbide-producing industry is toward simplification of grades, since 4 grades do about 85-90% of all the work that is done.

A great many "multiple-point" tools are being made with carbides at a total cost that is less than those made with other cutting materials. The carbide "content" of such tools is very low, the governing factor in their cost being the labor in making the tool; reamers, taps, broaches, milling cutters and burnishing tools are now made with carbides.

The greater use of carbide tools for cutting steels in Germany and England than in this country is not because of new or different carbides over there, but because of fundamental differences in the way in which the tools are made and used. Thus, production work in this country is multiple-tooled, while in Germany, for example, single tools are used generally, and the tools are larger in cross-sectional shank size. Nevertheless, at present 5-7 times as much carbide is being used for steel cutting in this country as 2 yrs. ago.

In using carbides for cutting steel, the horse power of the machine must be adequate since the tools must run faster. Tool design is important but now well standardized. Chip room in the machine is a real problem, and suitable chip breakers are required. The most satisfactory method of chip breaking is to grind the chip breaker in the tools (preferably to grind an angle obliquely across the front of the tool).

General-Purpose Carbide Systems

Evidence of 25% savings over high speed steel tools by the adoption of general-purpose carbide tools in his plant is offered by F. S. BLACKALL, JR. of Taft-Peirce Mfg. Co. ("Carbide Tools for Machining Small Lots", *Steel,* Vol. 107, July 29, 1940, pp. 54-56). The carbide tools are used economically on the smallest lots and even on single-piece jobs.

A "4-point plan" was adopted involving (1) the appointment of a "carbide application" man in full charge of the application, grinding and maintenance of carbide tools in all departments, (2) adoption of a minimum number of general-purpose carbide *tool designs,* (3) selection of a minimum number of general-purpose carbide *grades,* and (4) provision of adequate facilities for grinding carbide tools. To date carbide tools have been applied to 30% of this company's cast iron, aluminum, bronze and brass jobs and to 20% of the steel jobs.

The special importance of the first point of the foregoing plan—a system of centralized control of carbide practice—is emphasized by J. R. LONGWELL of Carboloy Co. ("The General-Purpose Use of Carbide Tools, I", *Modern Machine Shop,* Vol. 13, Aug. 1940, pp. 68-70). Thus, Warner and Swasey Co. attributes much of the success of its broad use of carbides (1500 jobs have been tooled up with Carboloy in this shop, with effective machine capacity increase 43% thereby) to the early establishment of a unified carbide control system. FPP (2)

Forming Aircraft Sheet

A Composite

The aircraft industry is now scrutinizing minutely every operation that can have a possible bearing on its attainment of rapid-production schedules. Notable improvements to date in one of the most important of the aircraft metallurgical engineering operations — sheet metal forming — have stemmed from developments in die materials and design.

The Guerin process as used at the Douglas plant is described in WESTERN MACH. & STEEL WORLD ("Cutting and Forming Sheet Metal Parts in Hydraulic Presses," Vol. 31, Aug. 1940, pp. 300-301). This process is a method for cutting and forming sheet materials with the use of only a single die in combination with a thick flat pad of resilient material, like rubber. The cutting blocks are usually 5/16 in. thick. The form blocks need be of metal only when hot forming or when high production is involved; Masonite and Pregwood are widely used. If metal blocks are necessary, they can be torch-cut from steel, sawed from aluminum or magnesium plate, or fabricated from cast zinc, Kirksite (a zinc alloy), scrap aluminum or magnesium.

The process is especially suitable for light metal sheet, as well as for light-gage stainless. If deep drawing is required, it can be done by progressive operations. Usually 25 sets of parts will warrant tooling up by this process. The uniform pressure applied through the resilient pad is said to eliminate local distortion and reduce to a minimum cold working of the metal; furthermore, the pad protects the finish of the metal being formed.

Zinc alloy dies are almost universally used for forming light gage sheet, but according to D. J. G. ROWE ("How Bismuth Alloys May Be Used for Sheet Forming Dies," *Sheet Metal Ind.*, Vol. 14, June 1940, pp. 639-640, 647), zinc has certain difficulties. A foundry with skilled workmen is required for producing zinc alloy dies and reclaiming used dies; also, special allowance must be made for shrinkage and warpage. Bismuth alloys, on the other hand, can be cast at low temperatures, no warpage is encountered, and the expansion on solidification results in castings of the exact size required.

Cerromatrix alloy [48% Bi, 14.5 Sn, 28.5 Pb, 9 Sb] is usually employed for the die, and the softer Cerrobase [58% Bi, 42 Pb] or Cerrobend [modified Wood's metal] for the punch. The die can be cast against a plaster or wooden model of the punch; the die is then coated with lamp black or paper and used as the mold for casting the punch.

The life of bismuth alloy dies is somewhat shorter than that of zinc alloy dies. However, steel or brass inserts may easily

be embedded in the bismuth at points where the wear is most pronounced. In spite of the higher initial cost of the bismuth, the die cost over a long period of time may be lower than that when zinc is used because of the amount of zinc lost as dross at each remelting. JZB (2)

Extrusion of Metal Powders

"EXTRUSION OF METAL POWDERS—A SURVEY OF SOME RECENT PATENTS". W. D. JONES. *Metal Industry, London,* Vol. 57, July 12, 1940, pp. 27-30. Review.

The recent announcement by Carboloy Co. that sintered carbide products are being manufactured by extruding powder into tubing, bars, etc., of various lengths focusses attention on the attractive possibilities offered by this method. Most articles made from powders require initial pressing in dies, and the size of such products is limited by available pressures. By extrusion it is possible to manufacture sintered shapes in sizes and lengths not hitherto obtainable.

In the design of an extrusion apparatus (several patents on such equipment are described) provision must be made for the insertion of the powder at some point, and this involves feed hoppers and feed devices to assure smooth passage of the powder. Feed pressure should be exerted in all directions simultaneously and feeding devices must be of the "non-return" type.

High frictional forces present in the extrusion of solid metals are not absent in the case of powders. This limits the ratio of the diameter and the applied stroke to a small figure. The addition of lubricants to the powder is helpful in reducing die wear and will permit a greater reduction in diameter in one extrusion operation than otherwise. Generally speaking, although the semi-compacted mass is more plastic at high temperatures, practical considerations make cold extrusion more attractive than hot.

If sintering is simultaneous with extrusion, the provision of a reducing atmosphere is essential but difficult, although the use of metallic hydrides might be of value in this respect. The sintering of a cold-extruded shape is usually done by direct passage of electric current through the piece, according to most patents.

One useful design (U. S. Patent 2,097,-502) involves a vertically-disposed die, with powder falling into the die set through one or more apertures directly on the faces of the ram. Thus the quantity of powder admitted per stroke is under some control, yet there is no possibility of the powder being pushed back into the feeding device during compression. In manufacturing tubes by this process the ram can be serrated so that a keying surface is provided to strengthen the bond between the two separately pressed sections. FPP (2)

Electric Salt Baths

A Composite

The electric salt bath will doubtless never succeed in banishing the messy externally-fired salt pot from the metallurgical engineering scene, but it has made and will continue to make impressive inroads. Electrically heated salt baths (together with internally-heated fuel-fired units) cost more than the old type of salt pot but pot life is longer, salt consumption is less and—most important, perhaps—heating is much more uniform and controllable with consequently better quality of work heated in the newer type of furnace.

The increased use of age-hardening alloys, particularly in the booming aircraft industry has expanded the use of electric salt baths, since most new modern salt-treating units are electric whereas many of the old type salt pots continue in use solely because of the investment still tied up in them. Of course, salt baths are not the only means of carburizing, cyaniding, hardening, tempering, age-hardening, annealing, brazing, etc. so that for every new installation they must compete with carburizing compounds or gas-atmosphere furnaces of one kind or another. In this ever-brisker competition the modern salt-bath units are at least "getting their share."

Case Hardening

An extensive discussion of salt-bath case hardening methods as used in England is presented by F. D. WATERFALL ("Case Hardening in Liquid Baths," *Iron Age,* Vol. 145, June 27, 1940, pp. 27-31; Vol. 146, July 4, 1940, pp. 32-35). This discussion (applicable to fuel-fired as well as electric baths) is concerned chiefly with salts, structures, and procedures. In general, the trend has been toward higher temperatures and stronger cyanide baths, with the bath surface covered with carbonaceous material to prevent excessive fuming and waste of cyanide.

Cyanide baths usually contain 40-50% sodium cyanide, and temperatures are ordinarily between 1650° and 1750° F. The use of a carbonaceous covering also increases the ratio of carbon to nitrogen in the case. In England the opinion is that a cyanide case is less brittle than a case of similar depth produced by pack harden-

ing, and tests show at least that cyanide cases are neither harder nor more brittle than pack-hardened surfaces.

The heating of parts made of oil-hardened alloy steels in cyanide baths to improve their wear resistance is widespread. Tests show that S.A.E. 5440 and 3250, for example, treated in 40-45% cyanide at 1560° and 1650° F. and then oil-quenched, closely approach the maximum surface hardness after 20 min. at 1560° F., with case depth about 0.009 in.

An interesting electric salt bath installation and practice for carburizing compressor parts is described by H. H. WHITTINGHAM of Norge Div., Borg-Warner Corp. ("Small Parts Carburized in Melted Salt," Metal Progress, Vol. 36, Sept. 1939, pp. 264-266). The furnaces are of the Ajax-Hultgren type, in which the heat is generated directly within the salt by electric currents passing between groups of immersed electrodes, which keep the molten salt automatically in constant circulation. Two batteries of 2 furnaces each are employed.

The practice at this shop comprises carburizing the parts in salt at 1650° F. for 4 hrs. in a large furnace, then transferring to a smaller salt bath furnace at 1450° F., allowing them to cool to that temperature, and then quenching in oil. In this way case and core properties are satisfactory and distortion is much less than if the parts were quenched directly into oil from the carburizing temperature.

The carburizing bath temperatures are controlled to within 2° F. of the desired temperature. After 4 hrs. at 1650° the work (S.A.E. 4620 forgings and parts from bar stock) develops a 0.035 to 0.040-in. case. The carburizing bath, a standard grade of commercial activated cyanide, contains 20-25% sodium cyanide, with a carbonaceous layer on its surface. The core has a hardness of 61-63 Rockwell C, with remarkable uniformity throughout each piece and from piece to piece. The average production of each battery of furnaces is 320 lbs. of small parts/hr., with power consumption about 20 kw-hr./100 lbs. of work treated.

Annealing Copper Alloys

Another Ajax-Hultgren installation, used in this case for solution-annealing of age-hardenable copper alloys is described by W. F. AYLARD & E. J. DUNN of Chase Brass & Copper Co. ("Electric Salt Bath," *Steel,* Vol. 107, July 8, 1940, pp. 70, 72-73.) The unit consists of a rectangular tank 12.5 ft. long, 2.5 ft. wide and 1.5 ft. deep (inside).

The bath employed is chiefly a mixture of chlorides that has suitable electrical properties; minimum attack on electrodes, tank, copper alloys being heated and handling equipment; minimum loss at high temperatures, suitable fluidity at operating temperatures; and resistance to contamination. A $\frac{1}{8}$-in. thick graphite blanket covers the surface. There are 6 pairs of electrodes located along one side of the tank; electrodes are of cast 28% Cr steel and are 2 in. square. They have a life of about 3 months at constant service.

Although the cost of this unit is high, it is easily justified by certain important metallurgical advantages. When the solution treatment, for example, is done at 1700°-1825° F. in ordinary fuel-fired furnaces, oxidation penetrates into the structure, and since the alloying elements are usually preferentially oxidized, response to age-hardening of the layer near the surface is seriously reduced. This is not the case with salt bath treatment. [*Neither, it seems, would it be the case in a furnace with a non-oxidizing gas atmosphere.*—F.P. P.] In addition, uniformity is excellent, and temperatures near the melting point can be reached in this salt bath furnace without the danger of overheating encountered in fuel-fired furnaces.

Heating Aluminum Aircraft Alloys

The practice of Fairchild Aircraft, Ltd. in heat treating aluminum alloys in electric salt bath furnaces is described in *Canadian Metals & Met. Inds.,* Vol. 3, July 1940, pp. 181-182. The alloys treated are 17 ST and 24 ST, both containing 96-97% Al with magnesium and copper. Received in the age-hardened state, they are heated in the furnace described at 920°-930° F. and quenched before forming and final age-hardening.

The salt used is a 50/50 mixture of potassium nitrate and sodium nitrate. Very little trouble is experienced from the salt's attacking the aluminum alloys, and furnace construction is simplified by the inertness of the bath to steel.

A brief note describing and illustrating the General Electric salt bath furnace in use for high-production heat treating of aluminum alloy parts at the Curtiss Aeroplane Div. of Curtiss-Wright appears in *Ind. Heating,* Vol. 6, Dec. 1939, p. 1140. The furnace, 15 ft. long by 3 ft. wide by $4\frac{1}{2}$ ft. deep, is heated by 24 immersion type heating units of 8.33 kw. each; the furnace is rated at 200 kw., 220 volts, 3-phase, and has a maximum operating temperature of 1000° F.

Brazing Furnaces

Recent adaptation of the electric salt bath furnace to some brazing operations has simplified them and reduced their cost, reports A. E. BELLIS of Bellis Heat Treating Co. ("Brazing with Salt Bath Furnaces," *Ind. Heating*, Vol. 7, June 1940, pp. 496-498). For such work salt baths are advantageous in providing uniform, constant-temperature heating, and constant and inert fluxing baths with freedom from decarburization and scaling. The salt bath makes brazing a short operation.

In electric salt bath furnaces of the Bellis type (described), the current is passed directly through the salt, between immersed electrodes and the pot wall. Contrary to expectation, neither the metal pot nor pieces of the work coming in contact with the electrodes short circuit the current. Such furnaces are applicable, of course, to carburizing, heat treating, annealing, etc. In brazing applications, the salt bath serves as both the brazing flux and heating medium.

Versatility of the electric salt bath method for brazing is emphasized by the fact that baths can be made neutral to the metals being joined as well as the brazing alloys. Stainless steel, for example, can be brazed to carbon steel by means of copper, brass or silver alloy. An interesting application is the brazing of tungsten carbide tips on steel.

The time of the operation depends on the size and thickness of the parts being heated and the melting point of the salt bath. A 1/2-in. diam. tube of 1/8-in. wall can be joined to a pressed metal collar of the same thickness with a brass melting at 1700° F. in a bath that is molten at 1000° F., in 90 sec. Dragout is about 1 lb. of salt per 100 lbs. of product brazed. X (2)

Metal-Spraying

A Composite

Developments in metal-spraying technique and equipment have considerably increased the use of this process for applying protective coatings, producing special-property surface layers or building-up worn or damaged parts. Applications, cost-reducing innovations, specific utility in oil-refinery equipment, and an examination of the wire-spraying process are covered in recent articles.

Two factors that have been most influential in recent extensions of metal-spray applications have been (a) lowered costs and (b) improvement in depositing efficiencies through the higher speeds and thicker deposits possible, reports E. T. PARKINSON of Metallizing Co. of America, Inc. ("Reducing the Cost of Metal-Spraying," *Steel*, Vol. 107, Sept. 9, 1940, pp. 46-49). Thus, a new wire-type gun with a special head that sprays steel or non-ferrous metals successfully and economically with acetylene, propane or natural gas has aided in reducing costs in some cases over 50%; metal can be sprayed at an hourly cost for gas of 25-30 cents if piped natural gas is available.

In the new guns, pressure can be varied about 50% and the gun will still have a neutral flame. Also because it is now possible to apply a single layer as thick as 1/2 in. with one pass of the metallizing gun, a much stronger, lamination-free deposit can be produced. Speed is better—about 30% faster spraying of steel can be accomplished, and in 1 hr's. run 8-10 lbs. of steel, 7-9 lbs. of aluminum, 15-20 lbs. of bronze or 30-35 lbs. of zinc can be deposited. A heavy-duty gun uses 3 lbs. of propane/hr. at an average cost for gas of 22 cents/hr. Oxygen consumption is 75 ft.^{3}/hr. Bond strengths, also, are now high —12,000 to 15,000 lbs./in.^{2}

Applications

A particularly advantageous application of metal-spraying is the rebuilding of worn crankshafts of many types; it is not difficult to make the journals 3 times as hard as the original journals. Aircraft parts—engine cylinders, tubular structures, fuel tanks, steel shafts—are other applications mentioned. Metallizing of engine cylinders is superior to painting for rust protection; on other aircraft parts—tubular structures, for example—metallizing makes a better base for subsequent painting than does the customary priming coat. In rebuilding of bearings and in rebabbitting, metal-spraying is widely used.

A refrigerating company is using a metal-spray gun and propane to spray 1330 ft.^{2} of zinc daily. On a performance test, 9332 ft.^{2} of zinc surface was deposited using 17 tanks of oxygen, 1 tank of propane and 760 lbs. of zinc.

In another instance, valve parts on a 2-in. blowdown valve in a power plant were metallized with 18/8 stainless steel, and their service-life extended to 3 yrs. where before it had been 1 yr. It takes but 15 min. to prepare a valve, 30 min. to spray and 30 min. to finish at a cost of about $3.50.

Oil-Refinery Equipment

A useful description of the utility and technique of metal-spraying oil-refinery equipment is given by D. R. JOHNSON &

E. K. DEWEY, JR. ("Metal-Spray Protection of Refinery Equipment," *Welding J., N. Y.*, Vol. 19, June 1940, pp. 397-401). Two types of spray guns are in general use today for metallizing, the wire-type in which the substance to be sprayed is fed to the gun in the form of a wire, and the powder-type in which the substance to be sprayed is first reduced to a finely pulverized form. Appropriate roughening of the surface to be sprayed will materially improve the bond.

The most important single factor in metallizing, either for corrosion protection or for building-up purposes, is the proper preparation of the surface to be coated. The surface should be prepared by sand blasting to pure base metal. The importance of keeping moisture away from the surface to be metallized cannot be over emphasized. In moderately humid weather, metallizing should be done within 4 hrs. of sand-blasting.

Several metals other than aluminum can be successfully employed for the protection of refinery equipment against corrosion. In a refinery at Artesia, New Mexico, the bubble tower of a cracking unit processing high sulphur topped crude had lost metal at the rate of 0.129 in. a year by localized corrosion and erosion. The tower was metallized in the corrosive zone with 12 coats of 18/8 stainless steel to a thickness of 0.020 in. The fact that erosion was important in this case would have meant certain failure if aluminum had been used. Three inspections following the installation of the liner indicate that successful protection has been secured.

Typical of the infinity of applications that can be successfully metallized are: the surface of storage tanks and drums, the ends of pipe still tubes, exchanger tube sheets, heads, shells and pump rods, for which aluminum, red brass, 18/8 stainless steel, zinc and lead have been used. Metal-spraying has become a valuable maintenance tool and is worth serious consideration by any company continually faced with corrosion problems or doing maintenance work where metallizing might be used to advantage.

The Wire Process

A practical review of the wire-spraying process, with useful data on operating practice with different metals, is given by W. E. BALLARD ("Metal-Spraying by the Wire Process," *Sheet Metal Ind.*, Vol. 14, July 1940, pp. 747-750). Metal-spraying pistols have 4 feeds: (1) the metal wire, generally 1-2 mm. in diam.—larger sizes give larger output, but the coating has a tendency to be more porous and to have more oxide inclusions; (2) gas with a minimum of 450 B.T.U. at 20-30 lbs./in.^{2}; (3) oxygen at a similar pressure; (4) compressed air at 40-60 lbs./in.^{2}

Aluminum coatings are widely used in the aircraft industry (usually 0.003 in. thick). Thicker aluminum coatings (0.007-0.008 in.) are used for furnace parts, aircraft exhaust systems, and for other parts requiring resistance to oxidation at temperatures up to 1800° F. In this case the aluminum-coated steel is heat treated at 1475° F. so that the aluminum is absorbed in the steel base. Tin coatings are used in the food industry. A recent innovation has been the use of metal-spraying to build up worn parts; generally, the built up part has better wear resistance than the original metal due to the greater porosity of the sprayed metal, which can retain oil films more easily than can an absolutely non-porous wrought metal.

As sprayed, the articles have a matte finish because of the previously sand-blasted surface of the article. Scratchbrushing will give a shiny satin effect. If the sprayed finish is to be polished, its thickness must be at least 0.010 in., so that the slight porosity on top can be polished out. Most common metals except chromium (which cannot be obtained commercially as wire) can be used for metal-spraying by the wire process. X (2)

2a. Ferrous

"Austempering" Iron Castings

A Composite

The process of "austempering" steel (completely described in METALS AND ALLOYS' Aug. 1939 issue, pp. 228-242) produces such improvement in the properties of steel parts amenable to the treatment and has such interesting possibilities that it is not surprising to learn of the development of analogous constant-temperature treatments applied to other ferrous materials. In two recent articles the use of constant temperature transformations to improve the properties of gray iron and of malleable iron is reported. The partial "austempering" method described by E. L. BARTHOLOMEW of United Shoe Machinery Corp. ("Gray Cast Iron—A New Heat Treatment," *Iron Age*, Vol. 146, Aug. 1, 1940, pp. 52-54) produces a marked improvement in physical and wear-resistant properties of gray iron castings. Thus an iron containing 3.25% T. C., 1.75 Si and 0.5 Mo heated to 1550° F. and held at heat 15 min. had a Brinell hardness of

341, tensile strength 75,500 lbs./in^2., and impact strength of 61 ft. lbs.

In contrast to steel, the austenite of cast iron is not fully transformed to bainite after normal holding times in the hot-quenching bath. The resulting structure, a combination of austenite and bainite, is believed to be responsible for the superlative wear-resistant properties of irons so treated.

This wear resistance was demonstrated by accelerated service tests on cams (a) as-cast, (b) oil-quenched and drawn to 360 Brinell, and (c) hot-quenched to 360 Brinell. The as-cast cam broke down in 30 min., and the quenched-and-tempered after 17 hrs.; the "austempered" cam, however, ran 105 hrs, and showed very little damage at the end of the run. An interesting feature of this austenite-bainite structure is that as work is done on the surface of a cam, for example, the surface austenite breaks down to martensite giving a highly wear-resistant martensite plus bainite surface cushioned by an austenite-bainite core.

The hot-quenched iron is readily machinable up to 300 Brinell. Because of the small amount of distortion, the part may be machined before heat treatment where a final hardness above 300 Brinell is required. A 2-in. section may be successfully treated but size is not necessarily a limitation where *surface* wear resistance is the prime requisite. Research to establish S-curves for cast iron is underway.

Test results obtained by subjecting pearlitic malleable iron used for commercial camshafts to an austempering treatment are presented by R. J. COWAN of Surface Combustion Co. ("The Heat Treatment of Malleable Iron," *American Foundrymen's Assoc.*, 1940, Preprint No. 40-19). Not all the carbides need be dissolved in the high temperature treatment, which may therefore be short, the purpose being in fact to produce a final structure containing both cementite spheroids and bainite, which is believed to be highly wear-resistant.

This is done by heating the pearlitic malleable iron to a high (hardening) temperature, holding for a relatively short time, then quenching into a liquid bath at a predetermined temperature and for a controlled time-period. The final hardness produced may be varied and controlled by regulating the temperature of and the time in the quenching bath, the high hardness values resulting from a long hold at comparatively low temperatures. X (2a)

New Pickling Process

"A REVOLUTION IN PICKLING METHODS." A. MCLEOD. *Sheet Metal Ind.*, Vol. 14, July 1940, pp. 715-721. Description of the de Lattre pickling process.

Pickling in sulphuric acid pickling baths is rapid and economical; furthermore, spent baths can easily be regenerated by cooling to remove the excess ferrous sulphate with the subsequent addition of enough fresh acid to bring back to the original strength. However, there are a number of disadvantages: (1) The high pickling temperature required (160°-195° F.), (2) the tendency to deposit carbon on pickled metal, and (3) a reduction in efficiency with increasing concentration of ferrous sulphate.

Hydrochloric acid pickles have some advantages, namely, they give a bright pickled surface and can be used at lower temperatures. The main drawback in this case is the lack of a commercial method of regeneration, while the high price of the acid and the possibility of hydrogen absorption by the pickled metal are minor disadvantages. Methods involving the simultaneous use of both acids have been proposed previously but have not been very successful.

The new pickling method is based on the reversible reaction:

$$FeSO_4 + 2\ HCl = FeCl_2 + H_2SO_4$$

The best bath composition is: 1 gram mol $FeSO_4$, 1-2 gram mols HCl, a special inhibitor consisting of gelatin peptonized by hydrochloric acid, and 1 gram mol H_2SO_4 per liter. The solution is used at about 125° F.

The $FeCl_2$ and the H_2SO_4 are the active agents in the solution. Pickling is continued until the concentration of $FeSO_4$ reaches 326-394 grams per liter, at which time it is necessary to regenerate the solution by removing excess $FeSO_4$. After regeneration, the solution is made up to its original volume by the addition of water from the washing tank which is already contaminated with a small amount of acid. The process is claimed to have the following advantages: (1) Rapidity, (2) thorough cleaning, (3) reduction of hydrogen absorption, (4) low steam and acid consumption, and (5) ease of regeneration.

Details are given of installations at two Belgian plants where acid consumption has been reduced to 38-60% of that formerly required. Two possible outlets given for the ferrous sulphate produced are the treatment of zinc ores and thermal decomposition to form sulphuric acid. The Belgian Government made the adoption of this process compulsory, because of the greatly improved working conditions as well as the elimination of any necessity for a system for disposal of spent pickling liquors.

[*As a bit of timely news and also some insight into the harrowing life of an editor of a technical journal, we should report that this article was written by an editor of*

"Sheet Metal Industries" who visited Belgium to get first-hand details. He had had an opportunity to visit only two plants when the Germans invaded the country. As a consequence, Mr. McLeod had a very adventurous trip getting back to England with the material for the article.—J. Z. B.]

A critical discussion of the process is presented in the next issue by J. W. T. ("Critical Discussion of the Data Provided on the de Lattre Processes," *Sheet Metal Ind.*, Vol. 14, Aug. 1940, pp. 829-830), along the following lines: In view of the relative activity of hydrochloric acid and sulphuric acid in attacking iron and iron oxides, it seems probable that the hydrochloric rather than the sulphuric acid is the active agent in pickling. However, if there is really little loss of hydrochloric during pickling, while the sulphuric acid is consumed, then the process seems to be nothing more than the regeneration of HCl in accordance with the equation given above, the tendency being for the excess H_2SO_4 to regenerate the HCl destroyed in pickling by reacting with the additional $FeCl_3$ formed.

De Lattre attributes considerable of the merit in the process to the use of a special inhibitor; his critic feels that most of the savings supposed to be due to the special process as well as the freedom from hydrogen embrittlement are merely due to the introduction of this inhibitor, which is common practice in all modern pickling plants regardless of the pickling solution used. The data given for the acid consumption prior to the introduction of the de Lattre process are typical of plants using sulphuric acid pickling solutions without inhibitors.

The economy of installing a regeneration plant is further questioned particularly in view of the uncertain market for $FeSO_4 \cdot 7H_2O$. Another factor to be taken into consideration is the suitability of present equipment for use with mixed acids. The only real advantage (other than a bright finish, which is often not necessary) seems to be the increased speed. JZB (2a)

Hard Surfacing with Boron

"SURFACE SATURATION OF IRON AND ITS ALLOYS WITH BORON." I. E. KONTOROVICH & M. YA. L'VOVSKII. *Metallurg*, Vol. 14, Oct.-Nov. 1939, pp. 89-99. In Russian. Research

Ingot iron and steels containing silicon, manganese, nickel and other alloying elements were saturated on the surface with boron at 1300°-1850° F. for various periods. The surface hardness was found to increase with increasing temperature and duration of the saturation process. The hardness was very high, reaching as high as 1200-1450 units (Brinell-Vickers).

The extremely high hardness is ascribed to the layer of Fe_2B. The depth of this layer depends on the composition of the steel, and is directly proportional to the temperature and duration of the treatment. Those elements that raise the A_3 point sharply reduce the depth of the saturated layer while those elements that lower A_3 increase the saturated layer somewhat. The greatest hardness after surface saturation was shown by the low-carbon iron alloys. BZK (2a)

Gas Welding Carbon-Moly Pipe

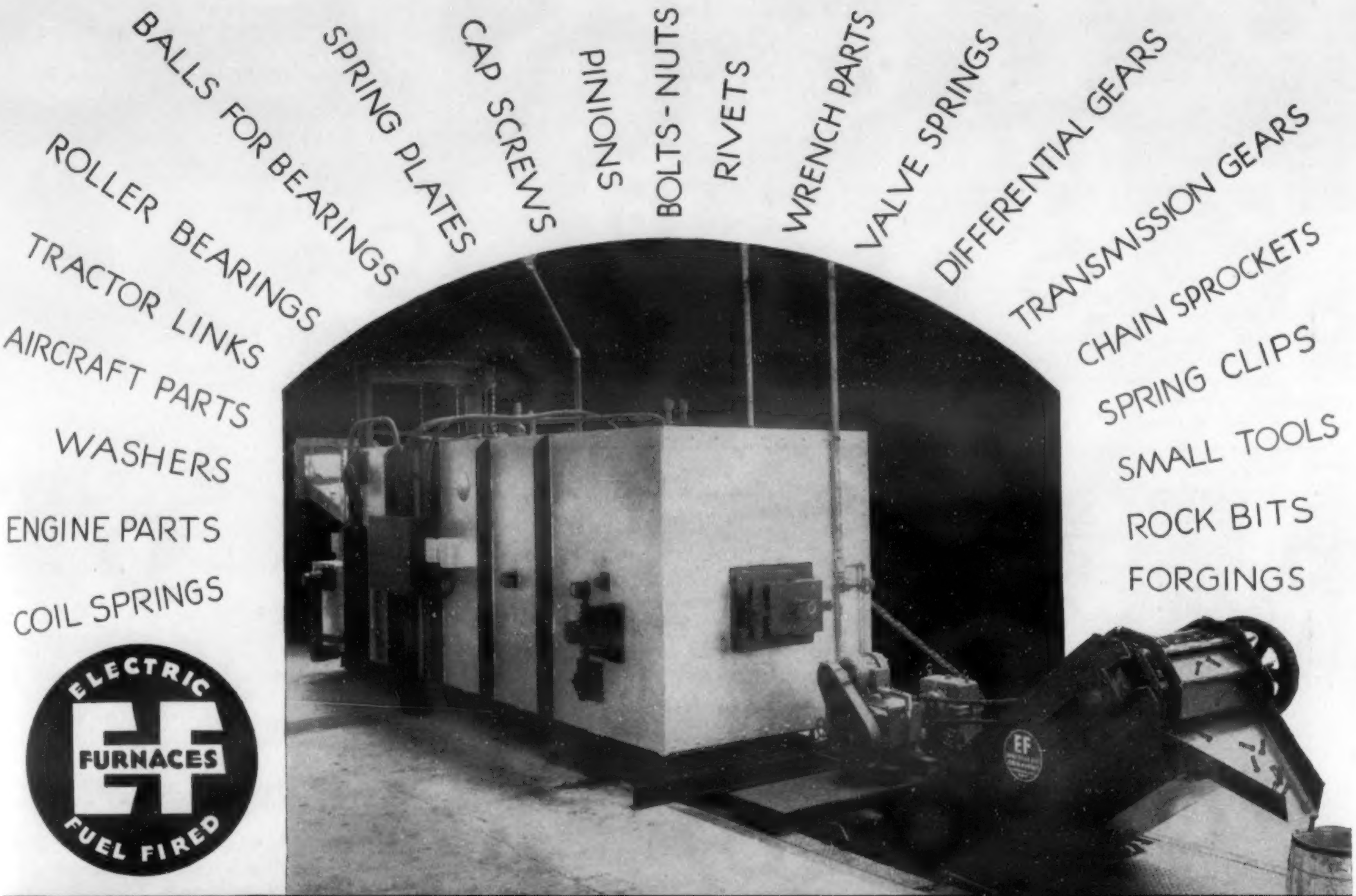
A Composite

Carbon-molybdenum steel piping is employed under practically the severest operating conditions to which power piping is subjected, and therefore requires the highest quality of welding. Nearly all such piping to date has been arc-welded with carbon-molybdenum steel electrodes. Forceful arguments for the use of oxyacetylene welding for such piping and operating technique therefor are presented in two recent articles.

Contrary to the common conception, oxyacetylene pipe welding is no slower nor more costly than equivalent competitive methods, claims A. N. KUGLER ("Oxy-Acetylene Welding of Carbon-Molybdenum Pipe", *Welding Engr.*, Vol. 25, June 1940, pp. 20-24). Data collected by a large eastern utility company on the welding of heavy-wall plain carbon steel pipe indicate that oxyacetylene welding is performed in ⅓ to ½ the time required by other standard procedures.

A series of field tests in which open single-vee butt joints were made without a backing-up strip or liner, are reported. The welds were stress-relieved by means of the oxyacetylene torch, heating the joint to 1400°-1500° F. and immediately wrapping and otherwise providing for slow cooling. [*Since the author suggests an increase in the temperature of stress-relief, it is to be regretted that no data are submitted comparing the properties of the weld with those obtained by the lower and more common treatment at 1100°-1200° F. At 1400°-1500° F. structural changes occur, and such temperatures are carefully avoided in most stress-relief annealing procedures.*—C.E.J.]

The welds develop an ultimate tensile strength equal to or exceeding that of the base metal. A hardness exploration conducted on the base metal, heat-affected zones and deposited metal indicate that the maximum is well below 200 Brinell. Separate pre-heating of carbon-molybdenum



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steel for oxyacetylene welding is not necessary. The inherent preheat available in the oxyacetylene flame is entirely adequate for the majority of joints made to date.

In addition to these field tests, one small installation has been completed in the middle-west. This system operates at 1800 lbs./in.^{2} and 900° F. and involves the following sizes of pipe: 2 in. by 0.438 in., 3 in. by 0.563 in. and 4 in. by 0.674 in. Multi-layer welding was employed and stress-relieving was accomplished with oxyacetylene torches at the temperatures and with the practice just described. Under test conditions and after approximately 1 yr. of operation, no leaks or failures of any nature have developed.

A comparison of creep stress values for carbon-moly and for other types of steel piping reveal the outstanding advantages gained through employing this alloy-steel for pipe to be used above 750° F. In addition, says E. R. SEABLOOM ("Oxy-Acetylene Welding of Carbon-Molybdenum Pipe," *Ibid.*, July 1940, pp. 23-26), carbon-moly displays only moderate air-hardening characteristics as compared to other high temperature steels, thus imparting good welding properties without danger of cracking.

Tests were conducted using the multipass back-hand method for making oxyacetylene welds of carbon-moly piping, using a 3/16 in. diam. rod. The welding torch was used for both pre-heating and depositing. The weld was completed in 3 hrs., after which it was stress-relieved with the welding torch, by heating the weld and the adjacent metal to a medium cherry-red color (equivalent to approximately 1300° F.). The physical properties of deposited weld metal exceeded those of the A.S.T.M. requirements, as failures occurred in the parent metal of the tensile specimen. [*It is interesting to note that the lower stress-relieving temperature suggested by this investigator is just below the* Ac_1 *transformation shown by the dilatometric studies reported in the paper. This choice of temperature seems more logical than that suggested by Kugler. Greater ductility can be expected from the higher stress relief anneal temperature, but other properties may not be so good.*—C.E.J.] CEJ (2a)

Welding Low-Alloy Steels

INVESTIGATION OF STATIC STRENGTH, NOTCH-IMPACT TOUGHNESS AND FATIGUE STRENGTH OF WELDED STRUCTURAL STEEL ST 52 AFTER DIFFERENT HEAT TREATMENT AND AFTER WELDING WITH PREHEATING ("Untersuchungen über statische Festigkeit, Kerbschlagzähigkeit und Dauerfestigkeit von geschweisstem Baustahl St 52 nach verschiedenen Wärmebehandlungen und nach Schweissung unter Vorwärmung") K. L. ZEYEN. *Tech. Mitt. Krupp, Forschungsber.*, Vol. 3, June 1940, pp. 87-98. Research.

Up to 1938, 1 million tons of the German low-alloy steel St 52 (0.14% C, 0.36 Si, 1.49 Mn, 0.020 P, 0.019 S and 0.37 Cu, with tensile strength of 75,000 lbs./in.^{2}) had been rolled, of which 80% was fabricated by riveting and only 20% by welding. A few failures of structures welded of this steel led to an investigation of its behavior, when arc welded, as affected by preheating, post-heating, subsequent normalizing, etc.

Welds were made with coated electrodes and with alloy-core electrodes. The properties of the steel were not unfavorably affected in butt welds with either type of electrode if the samples welded without preheating were heated to 480° F. or annealed at 1,000° F. after welding. The same holds good also for welds made at a preheating temperature of about 480° F. Normalizing improves the static test values but reduces slightly the tensile strength of butt welds with machined seams.

The samples with welded-on longitudinal and transverse beads, welded only with coated electrodes, showed after each of the applied heat treatments a considerable increase of mechanical strength. Coated electrodes gave in all cases higher values than alloy core electrodes for the notch-impact toughness of the seam, and their use also resulted in greater bending angles and a more favorable curve of temperature vs. notch impact toughness in the range of —100 to +750° F.; the strength of butt welds with machined weld seams was about the same for both types of electrodes.

Fatigue strengths of butt welds with machined seams were higher than those of unmachined samples, and transversely-welded seams had considerably lower tensile strengths than longitudinally-welded seams. Fatigue results depend very largely on whether the notch affecting the fatigue lies in or crosswise to the direction of the test load. Ha (2a)

Welding in Shipbuilding

"WELDING AND THE BUSINESS OF SHIPBUILDING." E. C. RECHTIN (Bethlehem Steel Co.) *Welding J., N. Y.*, Vol. 19, Apr. 1940, pp. 288-292. General review.

Welding is a comparative newcomer in the shipbuilding field, but is having a profound and far-reaching effect on both the technical and business sides of this industry. Gradually shipbuilding has progressed from welded barges and small tankers to larger and larger welded units.

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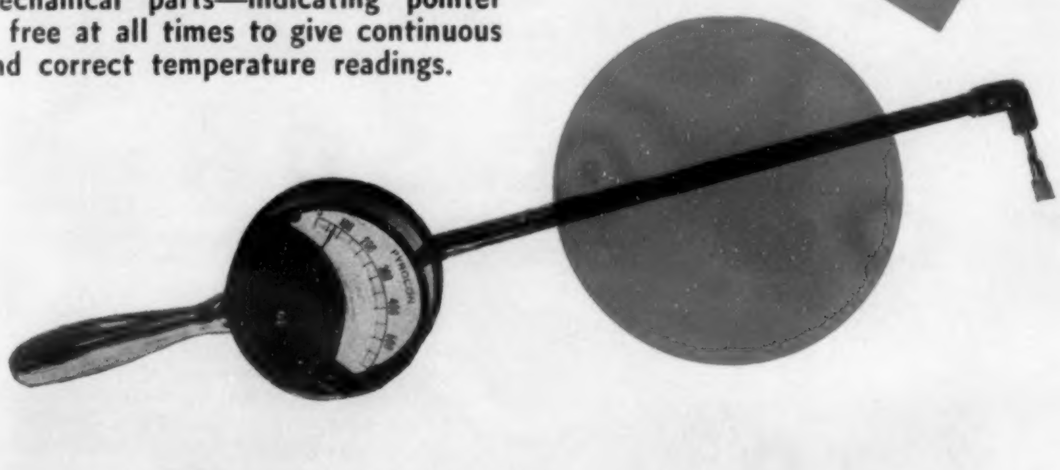

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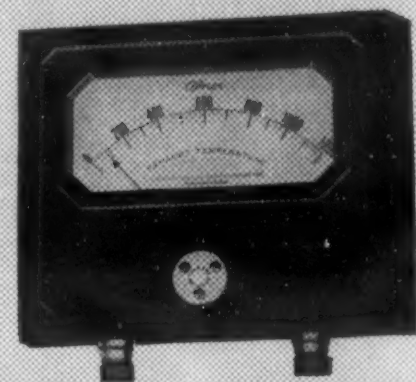

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in many years, and no revolutionary changes in riveting practice are expected. On the other hand, all development in welding is in the direction of reducing costs. Ultimately, the welded ship should cost less than any possible riveted one.

Welding can definitely be utilized to save steel weight. The saving can be employed either to increase the margin against corrosion or to extend the life of the ship, or it can be taken as a direct addition to the cargo carrying capacity. A recent report states that a saving of 13% can be readily made in hull steel weight by welding.

Design and fabricating factors are special for welding. A riveted structure has about 70% of the total fabrication man-hrs. spent in machine work before fastening the parts together. A welded structure uses only 30% of the total fabricating time prior to welding. The equipment that would fall short of being bare necessity for a large yard would mean an investment that would swamp the small builder. Yard equipment, generally, increases the speed and physical ease of doing the work. This means less labor costs on any given job.

Automatic welding equipment is not as far from the experimental stage as hand or manual welding. Any automatic weld is essentially a high-speed heavy-current operation making a large puddle of molten metal. This at present limits it to downhand welding. The extent to which automatic welding can be used goes back to assembly design and crane capacity with their attendant economic considerations. The lower limit of thickness for economic application of automatic protected-wire welding, in shipbuilding, at least, is about ⅝ in. The process attains its greatest value in the thicker plates where it has no competition.

CEJ (2a)

2b. Non-Ferrous

Polishing Before Plating

"A SHORT RESEARCH ON THE EFFECT OF BASIS METAL POLISHING ON THE CHARACTER OF NICKEL PLATE." W. L. PINNER (Houdaille-Hershey Corp.) *Proc. Am. Electroplaters' Soc.*, 1940, Preprint, 7 pp. Investigation.

The effect of polishing on the protective value of electro-deposited nickel coatings was studied, using 3 different types of steel and 12 different polishing procedures. The protective value of the coatings was evaluated by the salt spray test.

An improvement in protective value of the plate was obtained as the size of the polishing grain was decreased from 90 to 220 grain. A grease wheel gave better results than a dry wheel. Good results were obtained by polishing with a coarse abrasive (90 grain) and then following with a single pass of the fine abrasive (220 grain) wheel.

This treatment with the finer abrasive did not remove the scratches of the coarser abrasive, which remained visible, but probably only knocked off the tops of the scratches. A profilograph examination of the surface showed that the finer abrasive had reduced the average depth of the 90 grain scratches from 0.00005 in. to 0.000015 in.

AB (2b)

Spot Welding Aluminum Alloys

"RESISTANCE WELDING ALUMINUM AND ITS ALLOYS. A REVIEW OF THE LITERATURE TO JANUARY 1, 1939." W. SPRARAGEN & G. E. CLAUSSEN (Welding Research Commitee) *Welding J., N. Y.*, Vol. 19, July 1940, pp. 241-s—280-s. Correlated abstract.

Aluminum and its alloys are spot-welded by the same basic process as other metals. Aluminum alloys usually require surface preparation, and the conductivity, cleanliness and shape of the tip of the electrode are important. The properties of the welds, besides being influenced by machine settings, depend on the alloying elements.

The hard oxide film on aluminum surfaces is an insulator, through which the tips must crush before electrical contact is made with the metal. It is therefore recommended that the surfaces in contact with the electrodes be cleaned either mechanically or chemically. Chemical cleaning solutions must be well washed off or neutralized after application. The preferred method of mechanical preparation appears to be wire brushing, with buffers and sandpapers also used.

Aluminum has a high contact resistance compared with copper, but conditions favorable to absence of oxidation lower the contact resistance. Increase in pressure lowers the contact resistance. Too low pressure causes fouling of electrodes due to the high contact resistance and severe heating. On the other hand, the low contact resistance of Alclad calls for high currents and these involve rapid deterioration of the electrode through pick-up of aluminum.

The tip must fulfill three general requirements—(1) retain its shape for a considerable time under high pressure at operating temperature, (2) possess high thermal conductivity in order to remain cool, (3) form no alloy with the sheet. Alloys of a hard copper-base alloy (at least Rockwell B 60) are preferred by most authorities. The alloy may be of the heat-treated or precipitation hardening type, and high conductivity (at least 75% of pure

copper) is essential. Water cooling is essential for any tip material, except for large flat electrodes.

The total load is approximately proportional to the thickness. Starting with a minimum load of 150 lb. for two sheets each of 0.01 in. thickness the load is about 100 lb. additional for each 0.01 in. thickness of the sheets. At intermediate currents there is a considerable range of pressure over which welds of constant strength may be obtained. The duration of current is increased as thickness is increased; time increases rapidly as the thickness increases up to 0.06 in., beyond which time is approximately directly proportional to thickness.

Extreme accuracy of timing is not essential. In general, strength is more sensitive to changes in current than to changes in pressure and time. Excessive current may cause cracks and porosity. Welders based on accumulation-of-energy principle utilize extraordinarily high current for the thicker gages, if actuated by condensers, but may utilize currents of average intensity, if actuated in other ways. Spot welders for aluminum require transformers of high capacity. Electronic control is preferable for any machine.

The shear strength of spot welds in commercial aluminum increases from 100 lbs./spot at 0.020 in. thick to 800 lbs./spot at 0.130 in. With aluminum-manganese alloys (3S), shear strength rises from 100 lbs./spot at 0.020 in. thick to 1400 lbs./spot at 0.130 in. thick in cold-rolled tempers. Aluminum-copper-magnesium alloys (duralumin) show shear strengths that vary from 240 lbs./spot in sheets 0.016 in. to 1060 lbs./spot in sheets 0.059 in. thick. An alloy of aluminum with 2.5% Mg (52S) has a minimum shear strength that rises from 95 lbs./spot at 0.020 in. to 290 lbs./spot for 0.060 in. thick annealed material. The shear strength of aluminum-magnesium-silicon alloy (53S) is the same as in cold-rolled 52S regardless of whether heat treatment preceded welding. The minimum shear strength of Alclad 24S-T rises from 100 lbs./spot at 0.015 in. sheet to 780 lbs./spot at 0.070 in. Higher strengths have also been recorded. With Alclad 17S-T strengths of 350 lbs./spot for 0.032 in. sheet and 825-1230 lbs./spot for 0.064 in. thick have been obtained.

All the more common wrought alloys of aluminum have been spot welded. The thinnest sheet that has been welded is 0.002 in. Single sheets up to 3/16 in. thick (0.188) were welded in 1928 (2S and 51S-W), which seems to be the maximum thickness to date. Macrostructural examination of spot welds in aluminum and its alloys reveals the presence of a slug, indentation, and sometimes cracking or porosity; usually it is recommended that the slug occupy ⅔ of the thickness of the sheets. A 20% increase in strength due to heat treatment of spot welds in heat-treatable alloys is reported. CEJ (2b)

Adhesives and Cements for Metals

"Adhesives and Cements for Metals." *Light Metals,* Vol. 3, July 1940, pp. 175-181; Aug. 1940, pp. 202-209. Practical.

Adhesives find extensive use for the fixing of metallic components to metallic or non-metallic bases. Adhesives containing inorganic salts of the heavy metals must be used with caution, owing to the danger of corrosion, particularly when applied to light metals. The nature of the non-metallic backing to which the metal is to be fastened sometimes has a bearing on the question of corrosion. Dressing compounds, for example, may be leached out of the backing and initiate corrosion on the metal.

The requirements of a suitable adhesive are cost; ready availability, either by purchase or by preparation on site; stability in storage; ease of application; suitable rate of setting or drying; freedom from objectionable corrosive properties; suitable degree of hardness; sound adhesion to both surfaces; permanency under service conditions; specific properties such as color, water or oil resistance, electrical insulation, etc.; freedom from factory hazards like fire risk, health dangers.

Some important adhesives are as follows: *Plaster of Paris* may function as a filler-bond between two concentrically positioned components, for example, although neutral or acid sulphates are not recommended for contact with aluminum or magnesium. Another solid "cold cement" may be prepared from *glycerine and litharge.* This type of cement may be made water and oil resistant, and is often used for metal-to-metal-junctions. A similar cement may be made by mixing powdered citric acid and propylene glycol with water, china clay, and impalpable silica gel to form a paste, commonly known as *glycol-citrate cement.* This forms an oil and gasoline-resistant cement used for metal-to-metal, metal-to-glass or ceramic joints.

Shellac forms the basis of many joining materials. Shellac solutions or cements may be air-dried or baked, and find application in joining to themselves, or to metal, glass, ceramics, and plastics of the Bakelite or Beetle type. *Casein glues* have become well established for fastening plywood and veneers, and are used in light metal work as glues for fastening fabric coverings to metal, and metal veneers to metal-faced plywood.

Nitrocellulose cements although most commonly used in joining absorbent materials, have been successfully used in fastening felt to lacquered, enameled, or bare metal. A rough metal surface aids in adhesion. *Modified starch adhesives* or pastes made from starch or dextrine and nitrocellulose are surprisingly effective, and are often used for securing paper to aluminum and metals with very smooth surfaces.

Bitumens such as the coal tar pitches, fatty oil residues, etc. are somewhat restricted in use as adhesives because of the high temperature of application. However, they have the advantage of chemical inertness, stability, moisture resistance, flexibility, and adhesion. One use is securing aluminum foil to felted asbestos paper. *Paint and varnish-like adhesives* are now chiefly based on synthetic plastics. A Bakelite-rubber cement has been usefully used in fastening window glasses in metal frames; the cement can be softened by naphtha, and the glass removed when necessary. Glyptal varnishes have been used for rendering gaskets oil proof.

Rubber fixatives are widely used owing to good bonding properties and find special application in bonding metal to rubber in vibration damping and other applications. The Goodrich process is particularly noteworthy here, and consists in coating the metal with a benzene-cyclo rubber cement which is allowed to become practically dry before applying the rubber facing; the assembled job is then vulcanized and cooled under pressure. There are, of course, numerous other methods and processes for bonding metal and rubber. For example, the reaction between the sulphur in rubber and copper is employed in some processes. Rubber cements have almost universal application possibilities aside from metal-to-rubber joints; they are reported capable of sticking "anything to anything." AUS (2b)

1940 METAL SHOW

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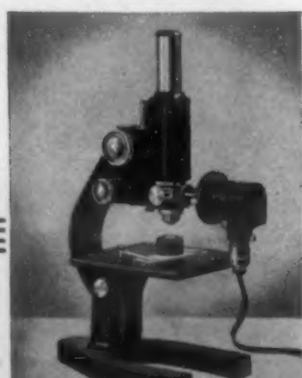


3 Properties and Applications

METALS, ALLOYS, METAL FORMS ENGINEERING DESIGN, METAL SELECTION

Physical and Mechanical Properties (including Fatigue and Creep). Corrosion and Wear. Engineering Design of Metal-incorporating Products. Selection of Metals and of Metal-Forms. Competition of Metals with Non-Metals. Specific Applications of Metals and Alloys.

Aircraft Ball Bearings

"TODAY'S BALL-BEARING METALLURGY." C. T. HEWITT (Fafnir Bearing Co.) *Steel*, Vol. 107, July 22, 1940, pp. 38-39, 76. Survey.

As many as 1100 antifriction bearings are used in a single airplane. In many cases such bearings are special, and some involve materials entirely different from those universally used. Non-magnetic materials must be used for bearings installed near magnetic compasses, so the use of K-Monel and beryllium-copper for rings, balls, and races has been perfected. These are also corrosion resistant. By heat treatment hardnesses of about 40 Rockwell C are produced in such alloys.

To resist corrosion, control bearings must either be made from stainless steel or be cadmium-plated. The stainless steel (1.10% C and 17% Cr) is heat treated to 60 Rockwell C, and though softer than steel in ordinary ball-bearings, is hard enough to furnish extensive life-expectancy where loads are not too high. Its corrosion resistance is nearly equal to that of K-Monel, and it is cheaper.

A type of control bearing, known as a rod-end bearing, is made from S.A.E. 4620 steel and has outer raceways integral with the housing with only the bore of the housing hard. The housing is copper-plated before the hole is drilled and the races and seal-grooves formed. Only these points are subsequently carburized, leaving about half of the wall thickness soft and tough to resist failure in service; the raceways remain hard to resist wear. The stop-off copper plating is removed after carburizing and the part is cadmium-plated.

The roller thrust-bearing that permits feathering of controllable pitch propellers operates under heavy centrifugal loads and is located on the blade shank. The shank hub of the duralumin blade is upset after the blade itself is forged. Thrust-bearing washers must be placed on the shank before upsetting, and thus are subjected to the precipitation hardening treatment undergone by the blade. The steel developed for these washers contains 0.55% C, 1 Si, 0.60 Mn, 7.5 Cr and 7.5 W. Its characteristics are similar to those of some tungsten hot-work steels.

Super-precision ball-bearings (described) for machine tools are often held to 0.00001 in. with balls gaged as closely as 0.000005 in. In modern railway roller-bearings, steel castings are used for housings instead of chromium-nickel-iron as formerly, and bronze replaces built-up steel sections for roll cages. MS (3)

3a. Ferrous

Heavy-Duty Brake Drums

"METALLURGICAL ASPECTS OF BRAKE DRUMS FOR HEAVY DUTY SERVICE." V. A. CROSBY & G. A. TIMMONS (Climax Molybdenum Co.) *Foundry* Vol. 68, July 1940, pp. 32-34, 83-84. Review.

For heavy-duty brake drums, cast iron offers the best combination of relatively high coefficient of friction and resistance to wear and scoring. Most drums that fail in service do so by heat cracking; many show excessive wear, while some failures are due to insufficient strength.

Drums made of cast iron with high carbon contents (3.50-3.80% C) are more resistant to heat checking than low-carbon drums. While soft plain carbon steels possess high coefficient of friction in contact with the brake shoe material, they tend to score in service. Drums of high-carbon steel have less tendency to score but become glazed by the formation of martensite on the braking surface, because the frictional resistance raises the surface temperature above the "critical"; when the brake shoe is released the surface is subjected to a metallic quench by the cooler body of the drum. The hard martensitic surface thus produced polishes readily, and the coefficient of friction between drum and lining is consequently reduced.

Although hard, brittle material also forms on the wearing surface of cast iron drums, the discontinuity of surface (because of the graphite flakes) prevents persistence of the martensitic layer. The surface layer is brittle and the high stress concentrations produced near each graphite flake during brake shoe application aid in removing the brittle layer as rapidly as it is formed. For these reasons gray cast iron is best for brake drums.

The problem is to increase the tensile strength of cast iron or to eliminate its tendency to heat check. Stresses produced within the drum may be as high as 30,000 to 40,000 lb./in.², and therefore the material must have good tensile strength at high temperatures. Thermal or heat checking and crazing are terms applied to the series of fine-hair cracks, arranged in a network pattern, that appear on a surface subjected to rapid heating by frictional resistance.

Beneath the surface layer, which may actually melt, the metal is raised to temperatures that cause simple thermal expansion on one hand and allotropic transformation on the other. The heated surface expands and becomes weak in compression while the cooler surface retains its dimensions and resists deformation. When the metal cools contraction produces stresses higher than the tensile strength, resulting in failure accompanied by the network of cracks, or crazing. Volumetric changes in ferrous alloys exhibiting alpha-to-gamma transformation are larger per unit rise (or fall) of temperature than those produced by simple thermal expansion, so that alloying additions that eliminate the transformation have possibilities.

The ideal brake drum iron must contain high carbon, between 3.60 and 3.80% C. Tests showed that sufficient alloy additions (0.50-3.80% Mo was used) increase the strength of cast iron with 3.80% C to a figure corresponding to that for lower-carbon (3.20-3.30% C) irons. This increase in strength increases the resistance to *upset* at the braking surface and also reduces the tendency to crack under the stresses set up by contraction during cooling. Additions that increase the physical properties of the matrix improve the resistance of cast iron to thermal checking.

Two alloy iron drums (0.49 and 0.79% Mo) were successfully tested for application where weight was not a vital problem; hence a larger section of a weaker iron was satisfactory and alloy content could be kept low. In another case service records show a 3.38% C, 0.55 Mo, 0.16 V iron to be still serving satisfactorily in a set of bus brake drums after 170,000 miles. For airplane brake drums irons containing 0.75% Ni, 0.75 Mo and 2.00% Ni, 0.50 Mo are in use. VSP (3a)

Some Properties of Cast Iron —A Review of A. F. A. Papers

A Composite

Many new data of value on the properties and structure of gray cast irons are found among the papers presented at the recent annual meeting of the Amer. Foundrymen's Assoc. The effects of copper on cast irons, the effect of sulphur on electric furnace irons, the relation between structure and performance of cylinder bores, and some observations on the pearlite transformation are all discussed.

Effects of Copper and Sulphur

Data accumulated during an investigation of the effect of copper on cast irons (see also "Copper Cast Irons" in our May 1940 issue, p. MA 282, and the article "Electric Furnace Cast Irons Containing Copper" in our July and August issues, pp. 37 and 158, respectively) are recorded by C. H. LORIG & V. H. SCHNEE of Battelle Mem. Inst. ("Damping Capacity, Endurance, Electrical and Thermal Conductivities of Some Gray Cast Irons," *Amer. Foundrymen's Assoc.*, 1940, Preprint No. 40-15). Work with copper additions from 0 to 3% showed that copper may benefit damping capacity at working stresses. As copper increases up to 3%, there is a slight decrease in the endurance ratio. It has only an insignificant effect on the thermal and electrical conductivity within the addition percentages investigated.

The effects of sulphur on both the melt-

ing behavior and mechanical properties of electric furnace iron were studied by FULTON HOLTBY & R. L. DOWDELL of Univ. of Minnesota ("Effects of Sulphur on Properties of Electric Furnace Cast Iron," *Ibid.*, Preprint No. 40-1). The authors made 40 casts of electric furnace iron in the form of various types of bars, and tested them for transverse strength, deflection, tensile strength, flowability (fluidity), machinability, hardness, contraction, depth of chill, chemical analysis and microstructure.

At about 0.18% S, there is a transition point in the properties of electric furnace cast iron. Up to that percentage, increased sulphur lowers transverse and tensile strengths and hardness, and increases deflection; at percentages above that figure, the reverse is true. An increase in sulphur will decrease the resulting manganese analysis, the decrease being more rapid in iron containing more than 0.18% S.

Flowability (fluidity) of the iron decreases rapidly at about 0.18% S, the fluidity remaining the same above and below this amount, provided manganese is held constant. Chill depth is not affected by sulphur, again provided manganese content remains constant. Finally, up to 0.14% S, machinability decreases; between 0.14 and 0.18% S it increases; and above the latter figure it again decreases.

Microstructure and Properties

Believing that microscopic examination of cylinder bore structures offers a valuable supplement to chill tests, hardness tests and analyses for control purposes, E. K. SMITH ("Cast Iron Cylinder Bores—Observations on Microstructure, Composition, Hardness and Wear," *Ibid.*, Preprint No. 40-3) offers proof in the form of data on structure and properties at the point of greatest wear in the bores—½ in. from the top. Analyses and hardness numbers are given and reasons are offered for either excellent, fair or poor wear experienced with the different microstructures observed.

There appears to be a relation between the amount of ferrite present in the structure and its wear resistance—the more ferrite present the greater the wear, provided normal, thin graphite flakes were present. The best cylinder bore structure, at the position of maximum wear, should consist of an entirely pearlitic matrix with long, thin flakes of normal graphite, no ferrite, and sufficient small particles of iron-chromium carbide to increase resistance to wear.

Studies of the pearlite transformation range in both the stable and meta-stable conditions of the iron-carbon-silicon system were reported by ALFRED BOYLES of Battelle ("The Pearlite Interval in Gray Cast Iron," *Ibid.*, Preprint No. 40-16). From test bars from 2 irons (2.93% T.C., 2.19 Si, 0.76 Mn, 0.064 S, 0.093 P; 3.03% T.C., 2.34 Si, 0.70 Mn, 0.063 S, 0.097 P), the author selected specimens and heat treated them so as to arrest the transformation at various points throughout the range. Micrographs show that ferrite, austenite and graphite exist in equilibrium within the range 1450-1550° F. for the irons studied.

The rate of formation of both ferrite and pearlite was accelerated at subcritical temperatures. Under identical conditions of heat treatment, an iron containing fine graphite flakes showed more ferrite than one containing large graphite flakes. Initial temperature of heating had an effect on the rate of formation of ferrite.

In small castings, examined by quenching at various cooling stages in the mold, ferrite began to form along the graphite flakes prior to the formation of pearlite, and continued to develop during the transformation period; no additional ferrite appeared after transformation was complete. Silicon not only promotes graphitization but also provides a mechanism for the formation of free ferrite. CMS (3a)

Corrosion (External) of Tin Cans

"PRACTICAL DATA ON THE CONTROL OF EXTERNAL CORROSION OF CANS." C. L. SMITH (Continental Can Co.) *Sheet Metal Ind.*, Vol. 14, June 1940, pp. 617-618, 620; July 1940, p. 727. Practical.

Rusting of empty cans in storage is generally the result of poor storage conditions or excessive humidity. Paper-covered rolls are conducive to rust formation as the moisture is retained for some time. Filled cans may corrode if any of the product being canned spills on the side of the can and is not washed off.

Tin cans may be corroded or etched by corrosive waters if the cans are processed in open kettles or under pressure in water; the cure for this condition is the addition of an inhibitor such as sodium chromate to the water. Condensates are sometimes contaminated by mechanical carry-over of impure boiler waters; installation of proper steam separators will prevent this condensate from reaching the cans. If retorts are improperly vented, air pockets may be formed that not only result in inadequate sterilization, but also lead to pitting and rusting of the can. The best cure is to close the retort after it has reached 215° F., so that the steam is given an opportunity to sweep out the excess air.

"Retort burning" is the name for dark-stained areas on the ends of cans in contact with rust-covered iron crate bottoms during processing. The action is probably electrolytic and is absent if the iron crates are

bright or if the crates are lined with sheet aluminum. However, in general, the stained area is not more susceptible to corrosion than the rest of the can.

Corrosive cooling waters can act as a secondary effect on areas exposed prior to cooling, as a corrosive agent on previously-unaffected tin plate, and as a means of setting up conditions conducive to subsequent corrosion in the warehouse. The first two effects can be prevented by the use of non-corrosive water (i.e. rain water) for cooling, or by the addition of inhibitors such as sodium chromate. The last effect (corrosion in storage) is the most dangerous.

Corrosion in storage has many causes. The cans are often cased when they are too cold and too wet, so ideal conditions for corrosion are present. Sometimes, too, the cooling water leaves hygroscopic residual salts on the can after the water has evaporated. Addition of sodium chromate is advantageous, as is the maintenance of low humidity conditions in the warehouse. Also, sweating or condensation of moisture from warm humid air on cold cans is a frequent source of trouble. JZB (3a)

Cast Iron for Car Wheels —Heat Treated vs. Chilled

"Wear Resistance Tests of Meehanite and Chilled Wheels for the Mining Industry." H. B. Coulter. *Western Mach. & Steel World.*, Vol. 31, July 1940, pp. 289-290. Practical.

Wear tests were made on heavy-traction wheels by loading them with a uniform weight and then sliding them backwards and forwards on standard rails. A chilled wheel with a Brinell hardness of 514 was compared with two high-strength iron (Meehanite) wheels, one of which had been quenched and tempered to 534 Brinell, and the other to 444 Brinell. The higher-hardness Meehanite had superior wear resistance to the other two wheels, while the chilled wheel wore more unevenly than the lower hardness Meehanite. However, castings should be heat treated to such high hardnesses only when the service does not involve impact. JZB (3a)

3b. Non-Ferrous

Die Castings vs. Permanent Mold

"Suggestions to War Time Users of Die Castings." A. Street. *Machinery (London)*, Vol. 55, Mar. 14, 1940, pp. 681-684. General survey.

Die castings and permanent mold castings are advantageous due to the minimum waste and minimum of machining involved; machining of either is necessary only if tolerances are narrower than ± 0.0015 in./in. Before the war, zinc alloy die castings were replacing cast iron in spite of higher material cost and because of the saving in machining; now this trend is being reversed in Great Britain because there zinc has to be imported. On the other hand aluminum is being conserved by substitution of aluminum brass or of zinc alloy in die castings and simple permanent mold castings.

Molds for permanent mold casting are generally made of plain cast iron or alloy iron and have a life up to 30,000 parts; for pressure die castings, alloy steel dies are used with a life up to 20,000 parts for copper alloys, 80,000 for aluminum alloys and over 200,000 for zinc alloys. Die castings can be made at the rate of 1000 - 1500 per shift compared with 250 for permanent mold castings. Permanent molds are accurate to ± 0.005 in./in.; die castings in zinc to ± 0.0015, in aluminum to ± 0.0025, and in copper to ± 0.003.

Permanent mold castings can be undercut, and sand cores can be used; die castings on the other hand can neither be undercut nor can sand cores be used. [*This statement requires some qualification. As pointed out in the composite "Designing for Die Castings" in our August issue, p. 214, a resourceful designer can break a few rules. While undercuts should be avoided in die castings, certain types involving extra die slides, collapsible cores, etc., are feasible; undercut regions can be machined out instead of cast with the undercut. Extremely complicated one-piece parts can be made by die casting.*—F. P. P.] The surface of pressure die castings is better than that of permanent mold castings. JZB (3b)

Corrosion Resistance of Zinc Die-Casting Alloys

Corrosion Resistance of "Zama" Type Alloys and Their Derivatives ("Sul comportamento, di fronto alla corrosione, delle leghe tipo Zama e derivate") R. Piontelli & F. Cremascoli. *Metallurgia Italiana*, Vol. 32, Apr. 1940, pp. 123-154. A summary of published work, plus original research; 91 references.

The addition of up to 4.5% Al increases the strength and refines the grain of zinc, but the resistance to aging is lowered, and intercrystalline corrosion takes place to an increasing extent as aluminum is increased. Small amounts of impurities increase the rate of corrosion of zinc alloys

notably. The addition of copper improves the tensile strength, elongation and weldability of the alloy.

The addition of magnesium to zinc-aluminum and zinc-aluminum-copper alloys tends to counteract the injurious effect of any lead addition by retarding intercrystalline corrosion. The formation of magnesium-zinc compounds, which separate as distinct phases, increases the hardness, but also makes the alloy more brittle, and reduces fluidity. Lead itself must be strictly limited to less than 0.005% for zinc-aluminum alloys, and to 0.007% for zinc-aluminum-copper alloys.

Lithium, although almost insoluble in zinc, induces the formation of finer grain with increased tensile strength and hardness. It also tends to counteract the effects of lead addition in a manner similar to magnesium. However, the oxidizability of lithium causes high losses during preparation of the alloy. The effect of cadmium parallels that of lead, and its content should be held below 0.005%. Tin increases intercrystalline corrosion markedly when present in amounts above 0.001%, and also reduces the workability. Nickel behaves somewhat like copper in improving the resistance to corrosion, but is more effective in the absence of the latter.
AWC (3b)

Vaporized Metals as Bearing "Grease"

"Lubrication in Vacuum by Vaporized Thin Metallic Films." Z. J. Atlee, J. T. Wilson & F. C. Filmer (Gen. Electric X-ray Corp.) *J. Applied Physics*, Vol. 11, Sept. 1940, pp. 611-615. Research.

The designers of a special type of X-ray tube, in which the target is rotated at a high speed, were faced with the problem of providing lubrication for the steel ball bearings of the rotating target. In the high vacuum required for X-ray tubes, ordinary lubricants are out of the question since any vaporization of the lubricant would spoil the vacuum and render the tube useless. Bearing temperatures, too, are likely to be as high as 400°-1000° F.

A thin film of metallic barium vaporized on the ball bearings greatly reduces the friction. Use of the barium film as a lubricant has resulted in a tube that not only operates more quietly but permits longer bearing life. Normally the barium coating will effectively lubricate an anode bearing for 50-100 hrs. of rotation, which corresponds to 36,000-72,000 diagnostic exposures. Previously such tubes had been operated without lubrication.

Application can possibly be made of the results described to other cases in which rotating devices have to be operated in vacuum. In addition, results obtained with films of chromium, aluminum, magnesium and zinc in air may have practical possibilities in rotating devices where organic lubricants are undesirable. FPP (3b)

Fatigue of Light Metals

A Composite

The light metals (aluminum, magnesium and their alloys) have inherently lower fatigue strengths than the heavier metals. Design engineers are learning, however, that this fact is not necessarily a barrier to their use for specific applications. For many of their most likely applications resistance to repeated stresses is not at all essential, for such stresses may either be entirely absent or well below the fatigue strength of the material. In others careful designing to reduce or eliminate stress concentrations may permit the use of light metals where the original design might have precluded it. In certain ranges a big question-mark still exists, for which data of use to designers are rapidly being accumulated.

Wöhler-type endurance tests or steel have demonstrated the existence of a "damage curve" which charts the course of the beginning of damage (formation of cracks), as distinguished from actual failure, in terms of load and number of cycles. Gustav Gurtler ("Untersuchungen über die Schadenslinie bei Leichtmetallen," *Z. Metallkunde*, Vol. 32, Feb. 1940, pp. 21-30) studied such damage curves on cast and wrought aluminum and magnesium alloys by means of fatigue bending tests.

Fine cracks develop after a number of stress cycles below that at which fracture takes place. The formation of these cracks is accompanied by a drop of impact strength and by a sudden increase in the amplitude of the bending. Observation of this change of the amplitude of bending offers a simple method of determining the "damage curve."

If the stress is plotted against the number of stress cycles that produce cracking, a curve is obtained that is below the S-N curve, but which has a similar shape and tends to merge into the latter at 20-30 million cycles with annealed Silumin, with aged alloys of the Duralumin type, and with aluminum-magnesium alloys. With cast Silumin and homogenized magnesium-aluminum alloys, the so-called "damage curve" remains well below the S-N curve even at a "high" number of stress cycles (100 million). The previous thermal and mechanical treatment has a pronounced effect on the shape and location of the "damage curve."

In order to observe the amplitude of bending, an automatic measuring device operating at a magnification of 3200 has been developed, which permits the detection at an early stage of the development of cracks on notched and smooth test pieces. Characteristic curves are given for several alloys after different thermal and mechanical treatment. The new experimental results on the "damage curve" are claimed to be of more value to the designer with respect to different materials and shapes than the conventional Wöhler curve.

Using a Schenck-type machine, Isamu Igarashi & Seikiti Fukai ("On the Fatigue Tests of Light Alloy Sheets," *Trans. Soc. Mech. Engrs., Japan*, Vol. 6, Feb. 1940, Abstract Supplement, p. S3; in English) tested 6 aluminum alloys, 2 magnesium alloys and some brasses and bronzes variously dimensioned, heat treated and finished. The most suitable test piece was 15 x 20 x 2 mm.

As expected, the surface condition of duralumin specimens had a pronounced effect—even light polishing increased the fatigue strength 9-24%. Aging had only a moderate effect, and cold working apparently offers no distinct advantages.

The same authors ("On the Influence of Alunite Treatment on the Fatigue Strength of Some Aluminum Alloys," *Ibid.*, pp. S1-S2) attempted to increase the fatigue strength of 3 wrought aluminum alloys by anodic oxidation. The tests were made with 18 mm. drawn bars anodized by Riken's method and tested in Ono's rotating beam machine, at 1700 cycles/min., and 10 million repetitions.

The results led the authors to conclude that anodizing does not improve mechanical properties and causes considerable loss in fatigue strength. The corrosion fatigue in a solution of 6% sodium chloride and 3% hydrogen peroxide is but slightly better than that of the untreated material.
EF (3b)

Testing and Control

4

METHODS, EQUIPMENT

Physical and Mechanical Property Testing and Inspection. Routine Control and Instrumentation. X-ray and Magnetic Inspection. Spectrographic and Photoelastic Analysis. Corrosion- and Wear-Testing. Examination of Coatings, Surface Measurements. Metallographic Structure and Constitution.

Spectrochemical Analysis

A Composite

Although spectroscopic methods of analyzing metals have been encroaching increasingly on the field of wet analytical methods, the latter will probably never be entirely replaced. The two types of methods are complementary; ordinary chemical methods are supreme in the high concentration range and in special analyses, while spectroscopic or spectrographic methods are useful for initial qualitative tests and excellent for quantitative, low-concentration work.

New Aids to Accuracy

This feet-on-the-ground appraisal of spectrography's relation to general analytical chemistry is found in editorial comment on p. 311 of the Aug. 1940 issue of *Gen. Elec. Review*. Speed and accuracy are required in both types of analysis; speed is obtained with the spectroscope by using photographic, photometric and electric accessories now available. Special techniques and accessories for increasing the accuracy and sensitivity of quantitative spectography are discussed by J. T. M. MALPICA of Gen. Electric Co. ("Quantitative Spectrographic Analysis," *Gen. Elec. Review*, Vol. 43, July 1940, pp. 288-297; Aug. 1940, pp. 333-335).

A method of relative intensities with internal standards, developed to reduce as much as possible the effect of the characteristics of the photographic plate in the intensity determinations, is shown to be independent of plate sensitivity, exposure and time of development. However, the spectral response of the plate is not eliminated and the lines under comparison must be close in the wavelength scale. Accordingly, a method of relative intensity ratios with *external* standards was developed to permit the making of intensity determinations completely independent of the photographic process.

Most difficulties in spectrum analysis arise in the light source itself. SAUL LEVY ("A Correlation Method for the Elimination of Errors due to Unstable Excitation Conditions in Quantitative Spectrum Analysis," *J. Applied Physics*, Vol. 11, July 1940, pp. 480-487) describes a method for evaluation and correcting errors due to unstable excitation conditions; originally due to Gerlach and Schwertzer. It is based on the use of 2 pairs of lines, a homologous pair (a line from the impurity and a line from the main substance that both change in the same way when excitation conditions are altered) and a fixation pair (a pair of lines from the main substance that behave differently when conditions are altered).

Steel Analysis

The spectrographic problem of determining very small percentages (around 0.05%) of alloying metals in low-alloy sheet steel rolled from "rimming" steel ingots and intended for deep-drawing operations is discussed by R. A. SAWYER & H. B. VINCENT of Univ. of Mich. ("Spectrochemical Analysis of Sheel Steel at the Great Lakes Steel Co.", *J. Applied Phys.*, Vol. 11, July 1940, pp. 452-458). The problem depended on the selection of a light source of correct sensitivity and reliability.

A serious trouble occurring in the spectrographic analysis of metals at low concentrations is that of obtaining satisfactory chemical analyses for calibration curves. Sample data of spectrum analysis of steel containing 0.03% Ni and 0.045% Cr show a standard deviation of 3% for the nickel and 5.2% for the chromium determinations, which means an accuracy of 0.01% or better in the actual composition determined. The spectrographic method will even permit determination of alloying metals in concentrations as low as 0.01% to around $\pm$0.001%.

Spectroscopic methods, as distinct from spectrographic, are used where the most rapid results are required. Usual methods give less accurate results than spectrographic and are, therefore, used more for identification and general classification than for accurate routine analysis. According to A. FISHER ("The Spectroscopic Analysis of Steels," *Wild-Barfield Heat-Treatment J.*, Vol. 14, June 1940, pp. 2-6), the speed of visual methods is remarkable; an intelligent boy can identify and estimate the content of 10 or so alloying elements in a few minutes. [*This "any bright lad" stuff absolutely does not apply to accurate quantitative spectrography.*—F.P.P.]

A two-prism spectroscope is generally satisfactory if the prisms are made of dense glass of high refractive index—say 1.65 to 1.70. As the collimator and telescope tubes are then approximately at right angles to each other, observations can conveniently be made without dazzle from the arc. Direct current, of course, is essential, 10 amps at 110 volts being generally satisfactory.

Non-Ferrous Metals

A very good review of spectrographic analysis—fundamentals, procedures, interpretation of results, equipment, etc.—is given by F. TWYMAN ("Spectrography in Non-Ferrous Metallurgy," *Brass & Aluminum Foundry*, Vol. 40, July 13, 1940, pp. 1, 2, 12; Aug. 10, 1940, pp. 1, 2, 5, 8; Sept. 7, 1940, p. 5; to be continued). Heterogeneity is believed to be the chief remaining cause of inconsistencies between successive spectrochemical determinations of the same specimen. Macroscopic heterogeneity effects may be minimized by using moving electrodes, and microscopic by selection of suitable inductance.

The consistency of spectrochemical analysis of non-ferrous alloys is from 2.5 to 7.5% of the per cent of minor constituent. Despite the popular assumption that many metalloids cannot be determined spectrographically, *all* the elements have sensitive lines, although those of many metalloids are of wave lengths shorter than those to which air is almost completely opaque. Such elements can therefore be determined spectrographically with the aid of vacuum apparatus and technique.

The applicability of the spectographic method to the analysis of lead and its alloys has long been known, but for reasons of cost and personnel qualifications has not been widely used for analyzing these metals. However, a detailed description of the procedure hopefully developed for the lead industry by Illinois University's Noyes laboratory is given by J. N. MRGUDICH ("Spectrographic Analysis of Lead and Its Alloys," *Iron Age*, Vol. 146, Aug. 29, 1940, pp. 21-25; Sept. 5, 1940, pp. 40-43). The development program, carried out at the request of a large storage battery company, has as its ultimate objective the evaluation of the effect of each common impurity in pig lead or grid metal in terms of battery production and performance. The analytical procedure described has been tested on more than 1,000 samples, it has been adopted by 3 important consumers and its results are accepted by at least 11 suppliers.

In qualitative spectrographic analysis the author uses a relatively large quartz prism rather than a diffraction grating. Identification of a "suspected impurity" line is done by matching the spectrum of the unknown sample with standard spectra. The limit of detection of the common impurities in lead are: copper and silver, 0.0001%; bismuth, 0.0003%; cadmium, tin and nickel, 0.0005%; antimony, 0.001%; and arsenic, zinc and tellurium, 0.01%.

In the quantitative procedure described, each unknown spectrum acts in effect as its own plate calibrating agent. The essential advantages of the method are that no extraneous calibrating spectra need be registered and that the plate area actually calibrated is more nearly the same as that on which is registered the impurity line to be measured.

Illustrative data are given only for the determination of silver in lead, but the same reproducibility was observed with copper, bismuth and cadmium. No difficulty has been encountered in checking silver and copper and bismuth in amounts less than 0.075%; between 0.075 and 0.10% Bi, spectrographic results run slightly higher than chemical. As indication of the speed of the method, in one day 18 pig lead samples were quantitatively analyzed for copper, bismuth, cadmium and silver, and qualitatively for arsenic, antimony, tin, nickel, zinc and iron. X (4)

Chromium Plate Thickness Tester

"AN ELECTROLYTIC CHROMIUM PLATE THICKNESS TESTER." STANLEY ANDERSON & R. W. MANUEL (Crane Research Labs.) *Trans. Electrochem. Soc.*, Vol. 78, 1940, Preprint No. 3, 10 pp. Descriptive.

The tester is based on the principle that the time required to anodically dissolve a chromium coating on a given area is proportional to the thickness. A small known area of coating is dissolved by means of a stripping cell, which consists of a conical brass tube to hold the electrolyte and a rubber gasket (1/16 in. thick) pierced by a hole 3/16 in. in diameter. The gasket is placed on the surface to be tested and is held in place by the tube, the end of which is placed concentrically over the hole. Stripping occurs only on the area of coating exposed by the hole.

The electrolyte consists of a solution that is 1.0 *N* in Na_3PO_4 and 1.0 *N* in Na_2SO_4.

The current density used is such as to strip about 0.000001 in. of chromium per sec. This amounts to 35 milliamps. for the 3/16 in. diam. hole. The endpoint is indicated by a sudden change in the current which is registered on a milliameter.

For measurements on curved surfaces the hole in the gasket has a diam. of 3/32 in. Although the thickness of chromium can be calculated from the current density and the area stripped (since the chromium is dissolved with 100% current efficiency) it is preferable to calibrate the instrument with coatings of known thickness.

Using this method the precision of measurements on flat and convex surfaces was about 2% and 5%, respectively. On concave surfaces the measured thicknesses were about 15% too high. AB (4)

Photocell Pyrometer

"Temperature Measurement with Blocking-Layer Photo-Cells." B. M. Larsen & W. E. Shenk (U. S. Steel Corp.) *J. Applied Physics*, Vol. 11, Aug. 1940, pp. 555-560. Experimental.

A photo-cell pyrometer for measuring temperatures in open-hearth furnaces is described. It is found that the chief advantage of the photo-cell is that it may be used to measure temperature changes at high temperatures with good precision and also enables direct recording of temperature data on standard recording apparatus. A detailed and dimensioned design is shown, which the authors have put to practical use. Its main limitation or obstacle is smoke or fumes which have to be avoided to obtain correct temperature readings. HFK (4)

Test-Piece for Steel Castings

"Design of Test-Pieces for Carbon Steel Castings." C. H. Kain & E. W. Dowson. *Foundry Trade J.*, Vol. 62, June 13, 1940, pp. 435-436. Original research.

The design of test-pieces that are representative of the metal employed in the manufacture of carbon steel castings is more important than generally recognized. For many years a block or coupon of the rectangular tongue type, from which two test-pieces could be cut in a plane parallel to the axis, was generally employed. This design is open to the serious technical objection that its square sections contribute to the formation of cleavage planes from the corners at 45° to the faces. Nevertheless, this method usually produced two test-pieces of reasonably uniform properties.

When, however, the tongue of the block was extended to provide a third bar, it was found that the three bars did not possess uniform properties. The bottom bar had the best properties, the bar immediately under the head the next best, while the center bar was slightly inferior. The explanation has been offered that the bottom bar consisted entirely of primary crystals, while the two above it had centers of secondary crystals, the formation of which in the narrow space between the primary crystals prevented the effective gravitational feeding of the middle bar.

The present paper deals with a three-test-pieces test block, designed to employ the principle of directional solidification by making the casting taper from the base to the feed head. In the ideal piece the bars must solidify under the same freezing and feeding conditions; as large an area as possible must be provided, from which primary solidification can proceed; and the test-pieces must be isolated from large bodies of metal that cause delayed freezing.

A final design of test block having a section resembling a clover leaf was adopted. These bars freeze under identical conditions. They have a uniformly large surface for primary freezing and, as the feed metal is introduced from the side, the section of the bar subject to stress during testing is remote from any large body of feed metal to cause delayed internal freezing. AIK (4)

Oxide Printing in Metallography

Utility of the Niessner Oxide-Print Technique ("Anwendbarkeit des Oxydabdruckverfahrens nach M. Niessner") F. Newirth, R. Mitsche & H. Dienbauer. *Archiv Eisenhüttenw.*, Vol. 13, Feb. 1940, pp. 355-358. Descriptive.

In the Niessner print method, oxide inclusions are revealed in the same way as are sulphide inclusions in the ordinary sulphur print. Photographic paper is soaked in 1:20 hydrochloric acid solution, and contact is made with the steel surface for a period ranging from a few seconds to about 2 min. The print is then brought to the desired bluish tint in a potassium ferricyanide solution for about 10 min. and the paper is fixed.

The section must be polished just as for microscopic examination to obtain clear prints. The method was thoroughly investigated and the results using varying techniques are discussed. Oxide inclusions and streaks are well brought out in the prints, although some alumina inclusions low in FeO and very small inclusions may not be revealed.

Whether the method can be used as a research tool or for control testing is still doubtful. SE (4)

METALLURGICAL ENGINEERING shop notes

Hardening High Speed Steel —Tongs, Tools and Tricks to Avoid Distortion

by G. B. Berlien
Lindberg Steel Treating Co.

The use of the right tongs and tools for handling parts made of high speed steel or other high-temperature-hardening materials will help to avoid trouble and may even determine the success or failure of the entire hardening job. Often, for example, a light tong is used on a heavy part or *vice versa*. Certain other aids to good handling practice are also worthy of mention.

There are several standard types of tongs with which everyone is familiar, but each type should be available in various diameter stock for good work. These for the sake of clearness are as follows:

1 

2 

3 

4a 

4b 

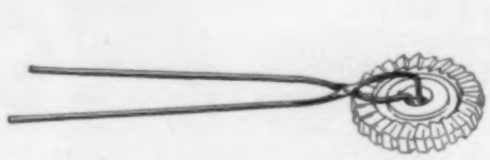
No. 1 is the flat nosed tong; No. 2, the hook; No. 3, the pick up tong; and Nos. 4a and 4b, two types of round-nosed tongs. These tongs, if available in three sizes, will handle 90 per cent of the average tools.

The first step in handling comes before the part is ever put in a furnace. Unless the part is one of a type the hardener has handled many times before, he should try the tongs on it, going through the motions of moving it in and out of the furnace to be sure there will be no slip when the part is at heat.

The availability of proper tongs is important, but the handling of work *in* the furnace should certainly not be ignored. It is an established fact that heating will be more uniform if the part can be elevated from the hearth of the furnace. Thus, the preheat can be fitted with an alloy grid to keep the work off the hearth, as described in the September issue of METALS AND ALLOYS, page 360. The high-temperature furnace may be fitted with a high-temperature refractory shape, preferably of the same material as the hearth. A convenient size for these is approximately 1 in. x $1\frac{1}{2}$ in. with lengths to fit the furnace. These runners should be placed lengthways along the hearth, and will not only aid heating but will keep the steel from contact with a refractory that may be pasty and tend to leave pit marks on the steel.

An ordinary sheet iron tray can be placed on the runners and the parts to be hardened then placed on the tray. The tray can be removed and water-quenched as often as desired to throw off any scale that has formed. Very light parts can be placed on the tray cold and brought through the heating cycle without individual handling by tong.

Tools such as comparatively thin milling cutters, etc., which have a fairly large hole in the center can be best handled with an inside tong made thus:



Pressure on the handle will force the jaws outward, holding the part by pressure of the jaws against the circumference of the hole. The very end of the jaw can be flared out slightly to force its way under the part. Heavy gear-cutting hobs are best handled with a sturdy round bar with one end upset to keep the hob from slipping off.

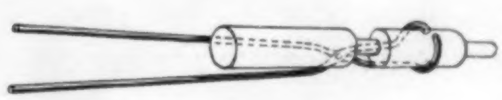
Tools that have light projections adjacent to heavy sections require extra care. If the part is so constructed that the light section will support the large section, the part should be placed in the furnace with the heavy section up. Thin protruding sections can sometimes be wrapped with asbestos cord before the work is placed in the furnace. Asbestos conducts the heat very slowly, so the entire part will come to heat at approximately the same time.

When it is not desirable to wrap a section with asbestos rope, the part can be preheated without protection, then immediately after it is placed in the high heat, a small "tent" of asbestos paper can be placed over the section. This will slow up the rate of heating so as not to burn the light section. If neither asbestos paper nor rope are available, the small projection can be chilled to a black heat in oil from the preheat; when the work is then placed in the high heat the temperature of the light section will be about 500 deg. F. lower than the body of the tool. The thin section will usually regain this heat before the heavy section is up to temperature.

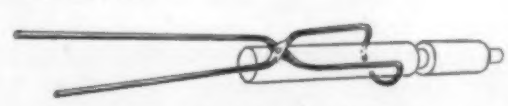
Another method of slowing up the rate of heating of a light section is to put a small section of cold firebrick or silicon carbide in contact with the light section immediately after the tool is transferred to the high heat. To allow the temperature to "even up," the refractory can be removed a few seconds before the tool is quenched.

Often tools are kept straight while heating only to be seriously warped during removal from the furnace. Tools that are difficult to pick up while in the furnace should be removed on a pan, placed on a convenient table and then picked up by tongs.

A pick-up type of tong used inverted will often support a long reamer or broach —this way:



Instead of:



A tool properly held in a tong can be allowed to air cool for a short time before oil-quenching. This will reduce the drastic effect of the quench without affecting the hardness. Of course, slightly more scale will form from contact with the air but usually not enough to cause trouble.

Good tongs and handling tools are inexpensive, and yet are so important a part of the hardener's equipment that they merit careful consideration.

Far from being impossible, the forge-welding of nickel-bearing steels is entirely feasible if a suitable flux is used. Plow manufacturers have obtained successful results in hammer-welding high-carbon nickel-chromium and nickel-molybdenum steels to low-carbon unalloyed steel through the use of a new flux, "E-Z Welding Compound," made by Anti-Borax Compound Co., Fort Wayne, Ind. Comprehensive tests have demonstrated that many S.A.E. nickel alloy steels, including S.A.E. 2340, can be forge-welded to themselves or to low carbon steel using this flux.

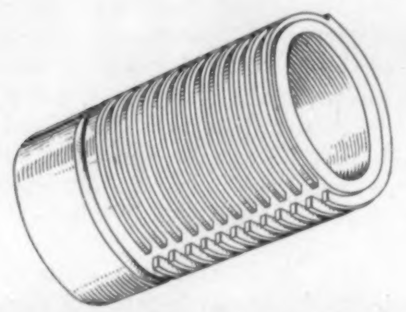
—*Nickel Steel Topics*, International Nickel Co., Inc.

(Continued on page 588)

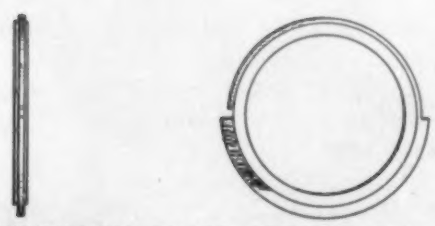
Multiple Die Castings vs. Stampings for Thin Rings

By R. L. Wilcox
New Jersey Zinc Co.

Unusual design and production problems were presented in economically manufacturing the stepped diameter ring shown in the accompanying drawing because of the close dimensions that had to be held. It will be noted that the flange of the ring has two diameters separated at one side by a notch. The thickness of the inner portion of the ring had to be held within the narrow limits of 0.089 and 0.091 in. whereas the flange, centered in this thickness, involved a step of 0.010 in. at each side with limits of plus or minus 0.002 in. on the steps.



FROM THIS SINGLE SLEEVE CASTING—



INDIVIDUAL RINGS ARE CUT OFF

If stamped, the ring would have had to be machined or swaged, which would have involved production difficulties or expensive dies, or both. If turned from bar or tubular stock, broaching or stamping of the smaller flange diameter and the notch would have been necessary and rather expensive. The rings could be die cast individually, of course, but if parted in the mid-plane of the flange or at one edge of the flange, thickness limits would have been difficult to hold with required accuracy, and the removal of the flash and gate would still have involved machining individual thin pieces.

A solution was found by the die caster, who produces the rings in multiples of twelve on a single sleeve casting parted through the plane of the sleeve axis and the notch. The sleeve has an extension at one end, where the gate comes, and this extension is used for subsequently chucking the piece in a lathe. There the bore of the sleeve (and of the rings) is readily sized within required limits by a simple boring or reaming operation. The flanges are faced readily to required thickness limits, and the rings are cut off with a parting tool that insures correct thickness of the ring proper.

The lathe operations are relatively rapid and simple and avoid the need for chucking or otherwise machining the rings individually, as would be necessary if they were cast separately. There is practically no loss in scrap, as the turnings and the chucking portion of the sleeve are remelted. If methods of production other than die casting were used, considerable loss in scrap would result.

The removal of "risers" from the necks of hardened steel rolls by their manufacturers may require days if the conventional turning method is used. On the other hand, the simple use of carborundum cut-off wheels enables the risers from an 18-in. neck to be cut off in 2 hrs. Two types of wheels are applied in succession—the first for the first 1/4 of the neck, and the second (slightly narrower and one grade harder than the first) for the remainder. The reduced width of the second wheel prevents binding and its higher hardness offsets the smaller arc of control.—"A Treatise on Roll Grinding," Carborundum Co.

Removing Weld Spots from Stainless Steel

by Herbert Chase

Spot and similar forms of welding are frequently used to advantage in assembling parts made from stainless steel. The metal is discolored, of course, where the welds are made and the oxidation spots show prominently, especially when the stainless steel has been polished. Although the spots can be removed by grinding and buffing, this may entail considerable labor and perhaps leave slight depressions which sometimes stand out prominently in the reflected light from the polished surface.

Such spot weld marks can be removed by "reverse plating" in which, of course, the work is made the anode. Unless the surface at the weld is unduly rough, the polished surface is restored and requires no further polishing or buffing. Naturally, such work is done to best advantage on products small enough to be immersed in a plating tank of moderate size and the cost should be lower than that involved in buffing if a fair volume of work is to be handled.

The actual operation—a sort of localized electropolishing—may be performed using any one of a number of electrolytes, and current and temperature conditions that must be determined for the size, shape and analysis of the part. A number of proprietary electropolishing baths that would doubtless do the trick have been described previously (see "Commercial Electropolishing of Stainless Steel," METALS AND ALLOYS, Feb. 1940, p. MA 88, and "Electropolishing," Sept. 1940, p. 322).

Occasionally a job of air-hardening steel will warp excessively—and unaccountably—during treatment. This may be the result of unequal cooling caused by a draft hitting one side of the piece. A useful corrective is to perforate the bottom of a small drum or tin can, support it off the floor a few inches and then set the work to be air-quenched inside. A medium-sized oil drum or a large paint can is about the right size.—*Heat Treating Hints*, Lindberg Engineering Co.

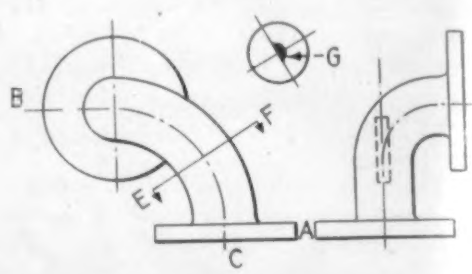
Send in your "shop notes." The editors will pay for all original material accepted.

For melting the zinc alloy (Kirksite) now widely used for drop hammer dies in stamping out aircraft parts, a pot made of alloy iron (3.40% total C, 1.60 Si, 0.60 Mn, 2.20 Ni and 1.10 Cr) will give many times the life of a plain cast iron or wrought steel container.
—*Nickel Cast Iron News*, International Nickel Co., Inc.

Doweling Foundry Patterns

Although the insertion of either an iron plate or a brass plug and socket dowels is a simple matter, the question of the doweling of the two halves of a pattern sometimes arises and cannot be so easily disposed of. Particularly is this true when the pattern cannot be jointed through the horizontal plant but has to follow the centerline of the required casting.

Such a case is illustrated in the diagram, which shows a double-turn pipe. Joints in the mold have to be taken at A and B, following the centerline BC. This pattern



could, of course, be made solid and the top-half lifted off, and for a "one shot" job this would be the best method to adopt. In this particular case, however, several castings were required, and a jointed pattern would make for a cleaner mold and would be easier to ram up, especially if a joint board were supplied.

As can be seen, the insertion of orthodox dowels was out of the question and the difficulty was surmounted by securing a fairly long tongue to one half of the pattern. This tongue followed the contour of the joint and in the other direction had a generous taper imparted to it. A suitable recess cut in the other half of the pattern ensured correct location, the taper allowing the top to be easily lifted without tearing done the sand.

The dotted lines illustrate this novel dowel, while a section of the pattern through EF is shown at G.—*Foundry Trade Journal.*

Oil-soaked wrapping paper can be used to keep sheet steel from breaking in a forming press, reports a metallurgical engineer who was faced with persistent sheet breakage at the top edge of a deep and wide cup being drawn in one end of a rectangular sheet of steel. No time was available for redesigning the dies, but a sheet of oil-soaked brown wrapping paper laid on the lower die and under the steel sheet allowed proper feeding and eliminated breakage. One sheet of paper was good for 12-15 sheets of steel.
—*Steel Facts*, American Iron and Steel Institute